Biofuels and Salinity Management in the Western San Joaquin Valley

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California Energy Commission

December 5, 2008

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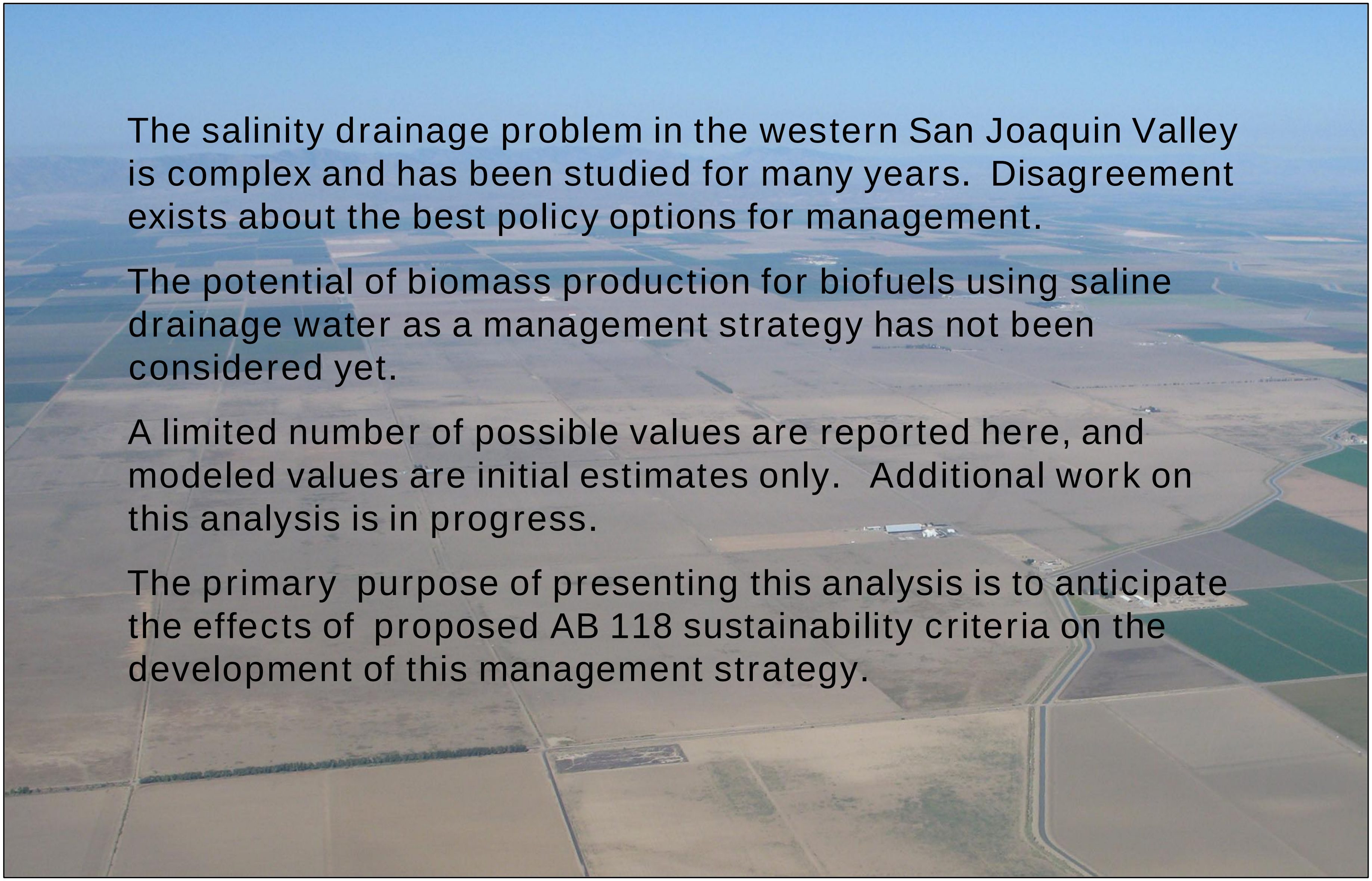

The salinity drainage problem in the western San Joaquin Valley is complex and has been studied for many years. Disagreement exists about the best policy options for management.

The potential of biomass production for biofuels using saline drainage water as a management strategy has not been considered yet.

A limited number of possible values are reported here, and modeled values are initial estimates only. Additional work on this analysis is in progress.

The primary purpose of presenting this analysis is to anticipate the effects of proposed AB 118 sustainability criteria on the development of this management strategy.

Retired farmland in former Broadview Irrigation District

Biofuels and salinity in the WSJV

- An overview of the salinity drainage problem
- DW reuse for forage production
- Economic and environmental costs of salinity and Se management
- Conversion of biomass to energy (ethanol and electricity)
- AB118 salinity standards

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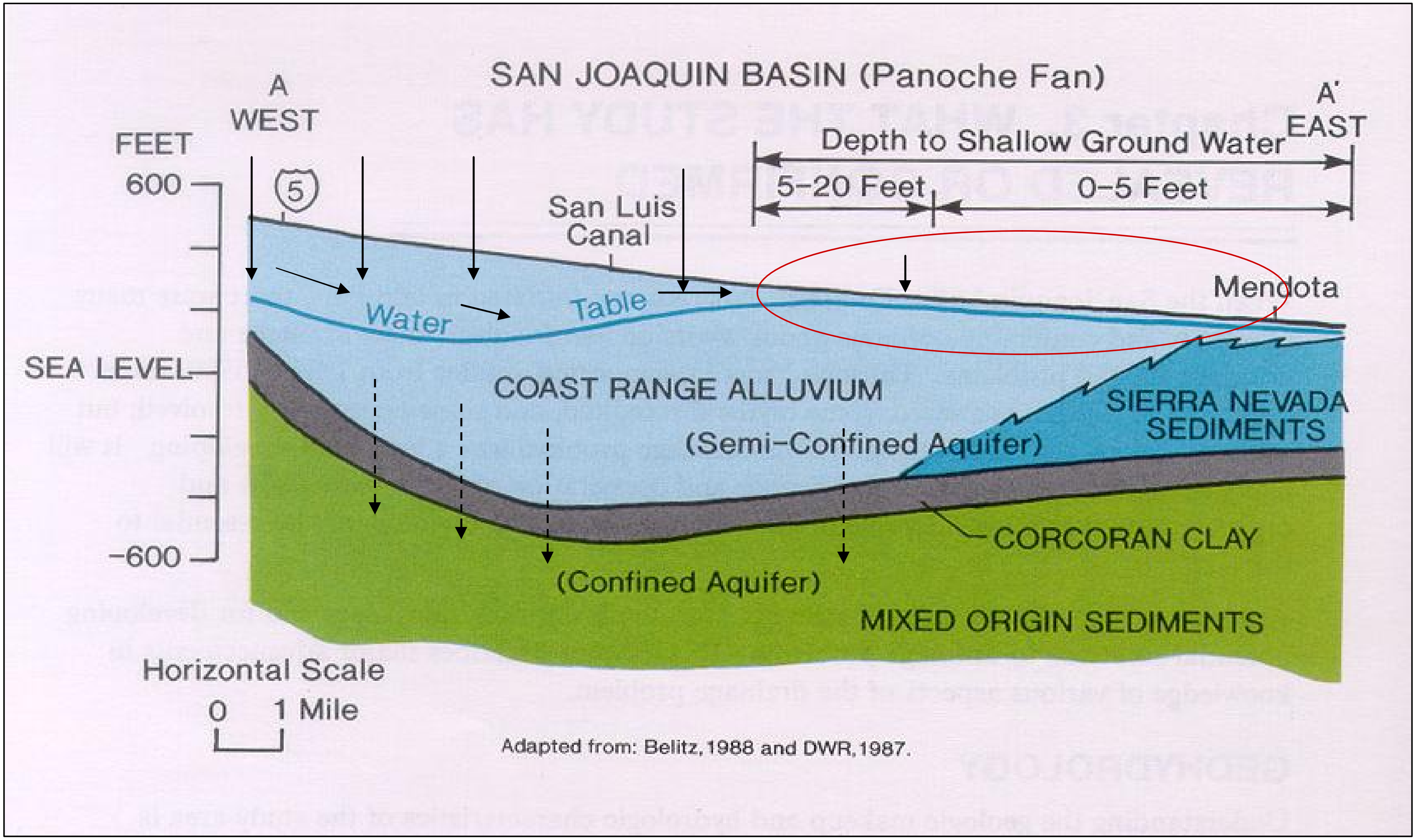
Lift Pumps, State Water Project

Irrigated agriculture in the San Joaquin Valley

The irrigation of semi-arid/arid landscapes cannot be done without loss of salts to groundwater.



Groundwater behavior in the WSJV

Saline soil near Stratford

Shallow, saline water table

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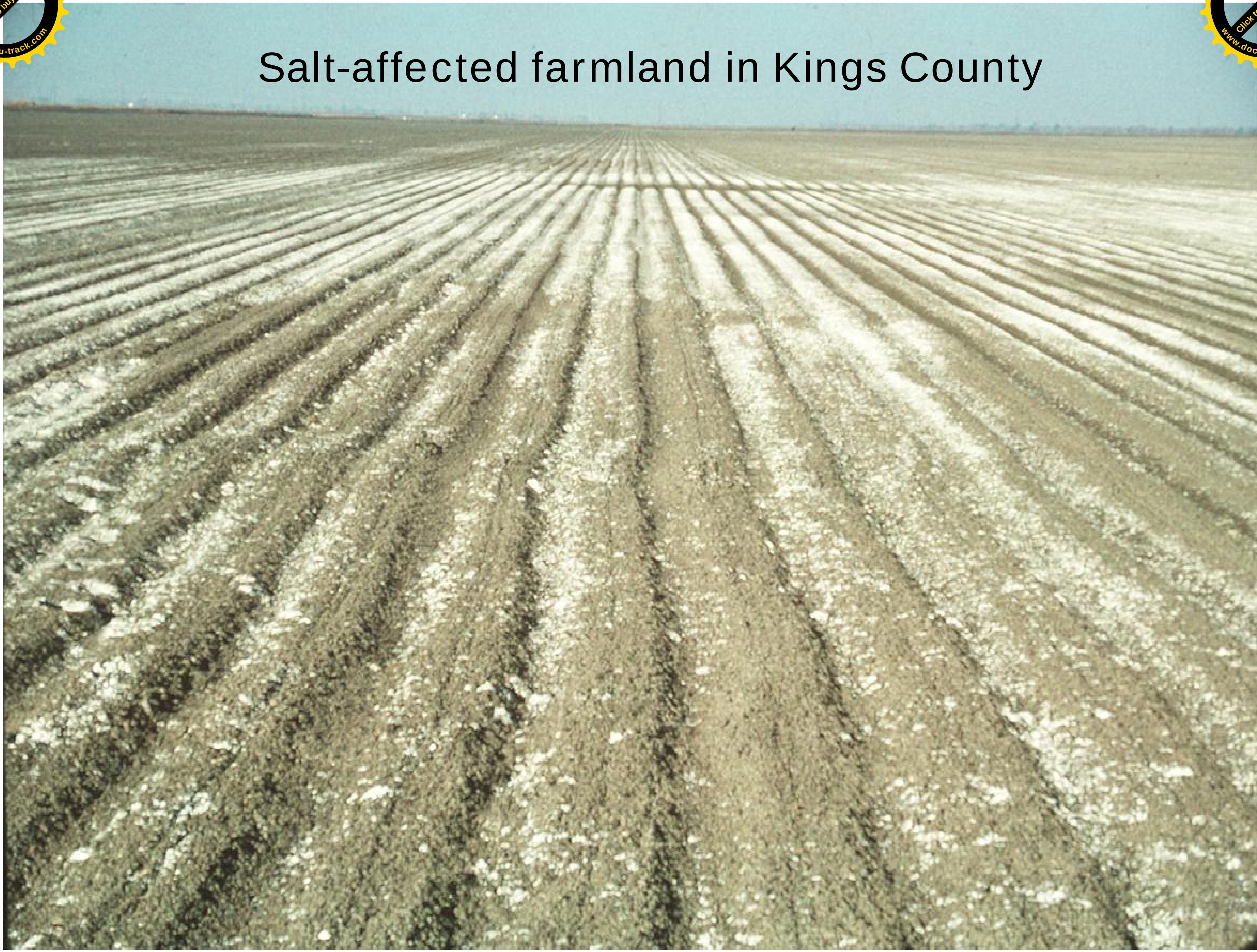
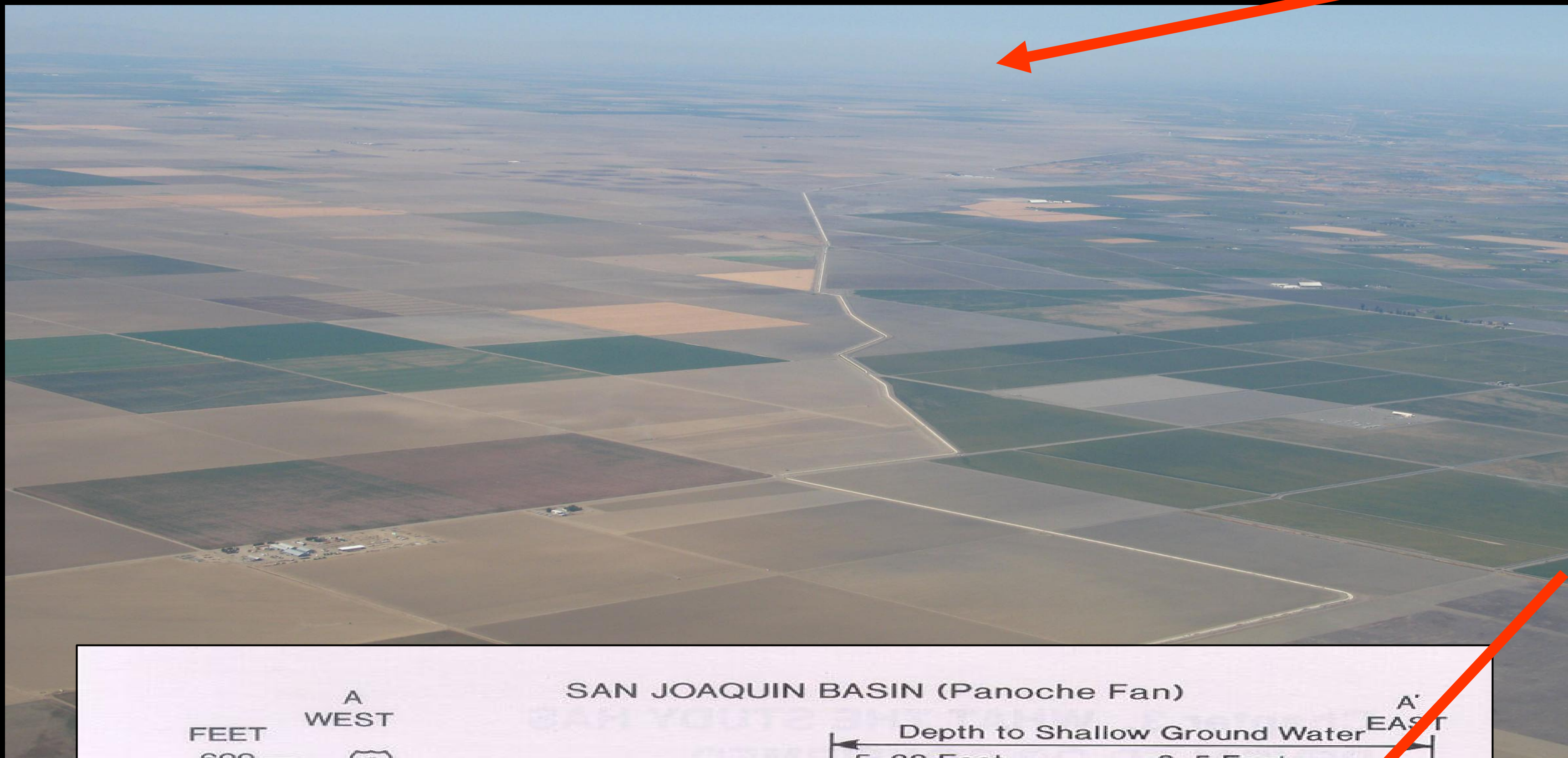
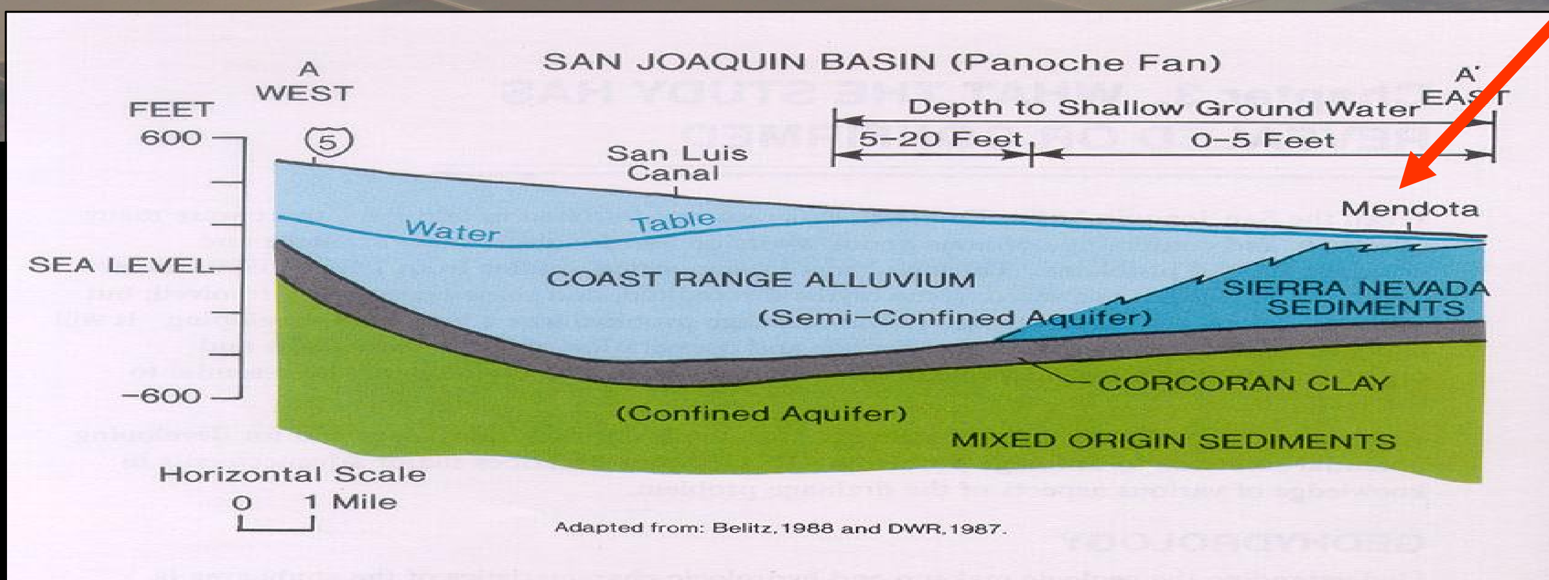
Salt-affected farmland in Kings County



WSJV on left; ESJV on right about 25 miles south of Mendota





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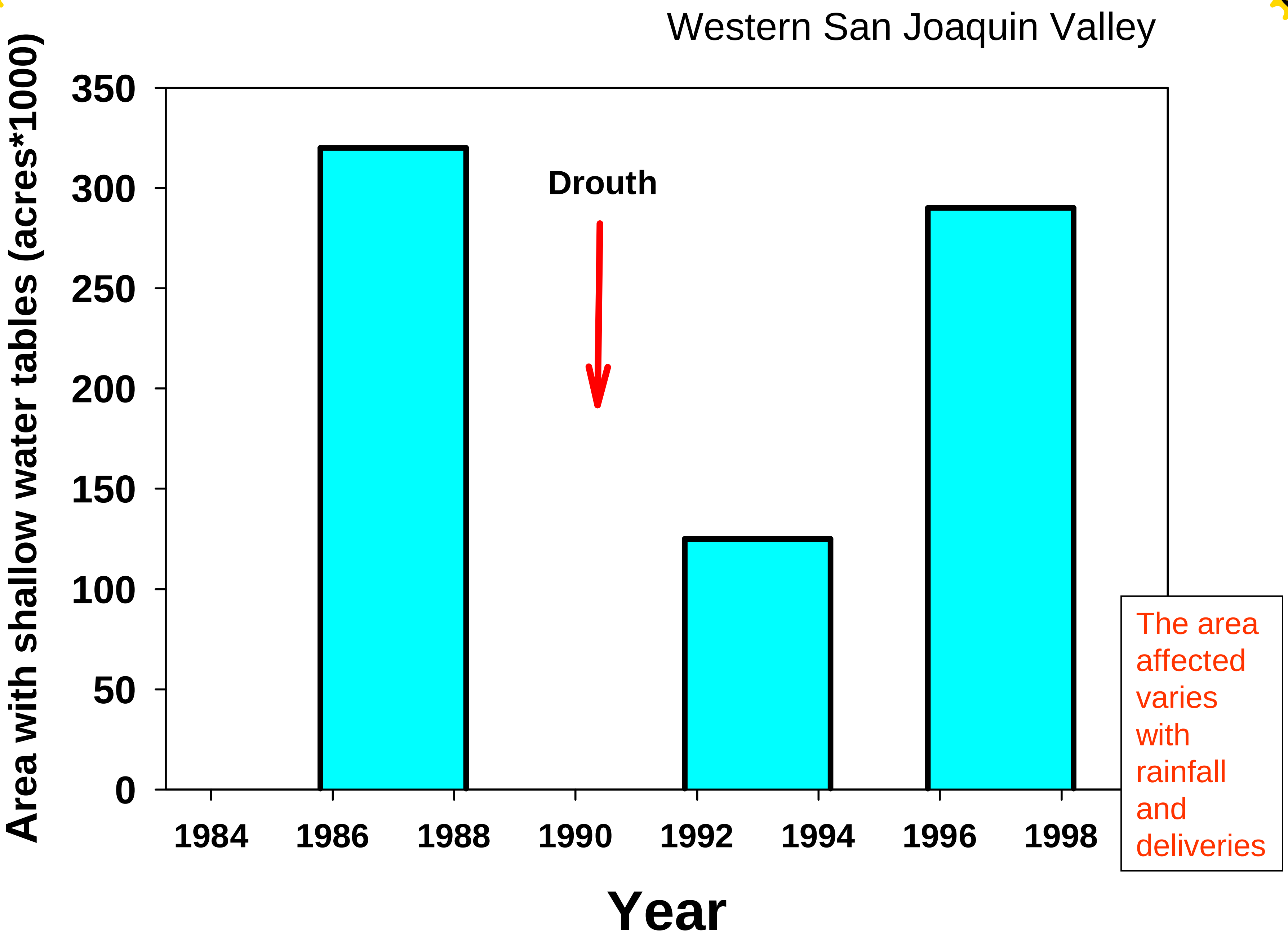
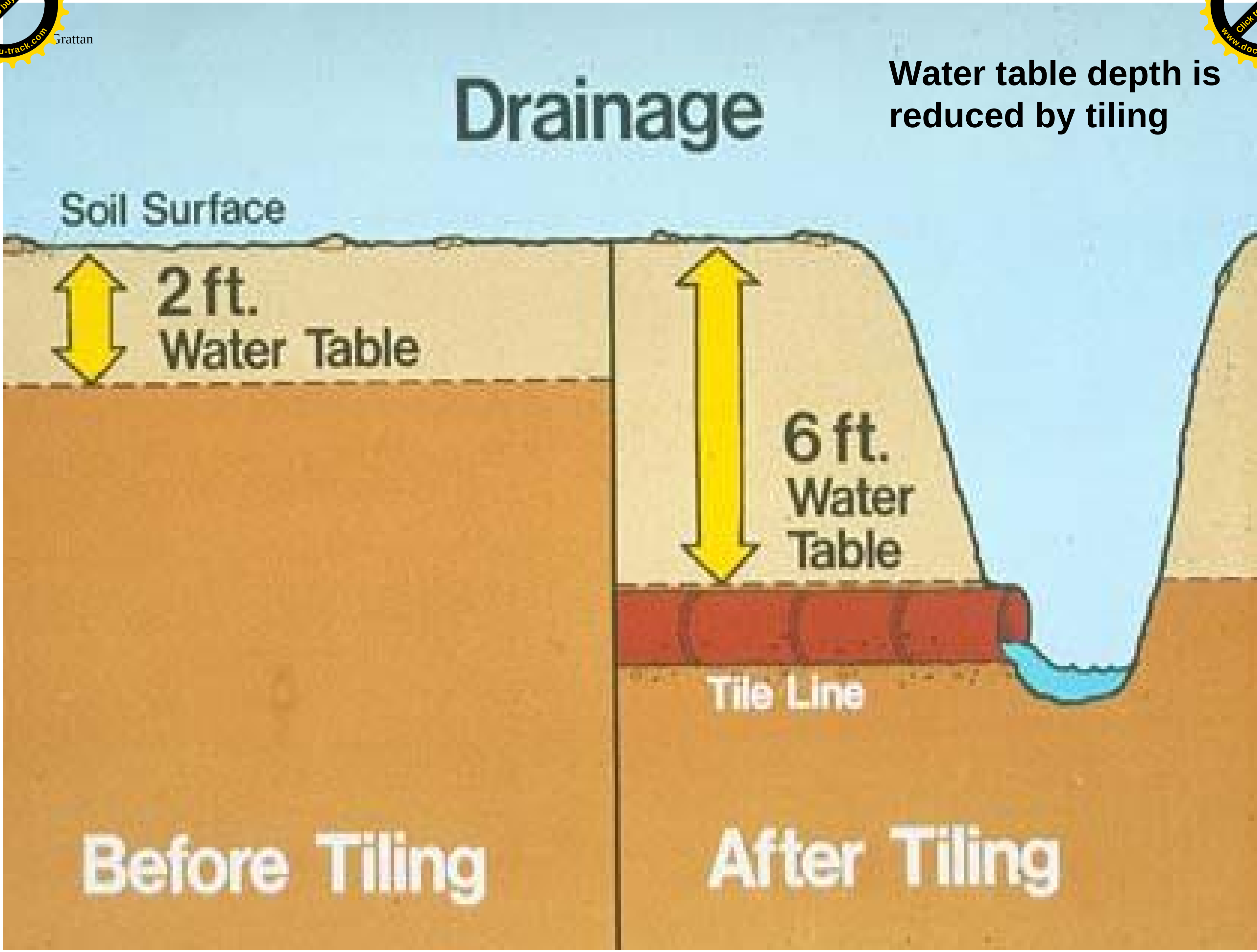


Western San Joaquin Valley
Area with shallow water tables (acres*1000)
350
300
250
200
150
100
50
0
Drouth
1984
1986
1988
1990
1992
1994
1996
1998
Year
The area affected varies with rainfall and deliveries

Grattan

Water table depth is reduced by tiling



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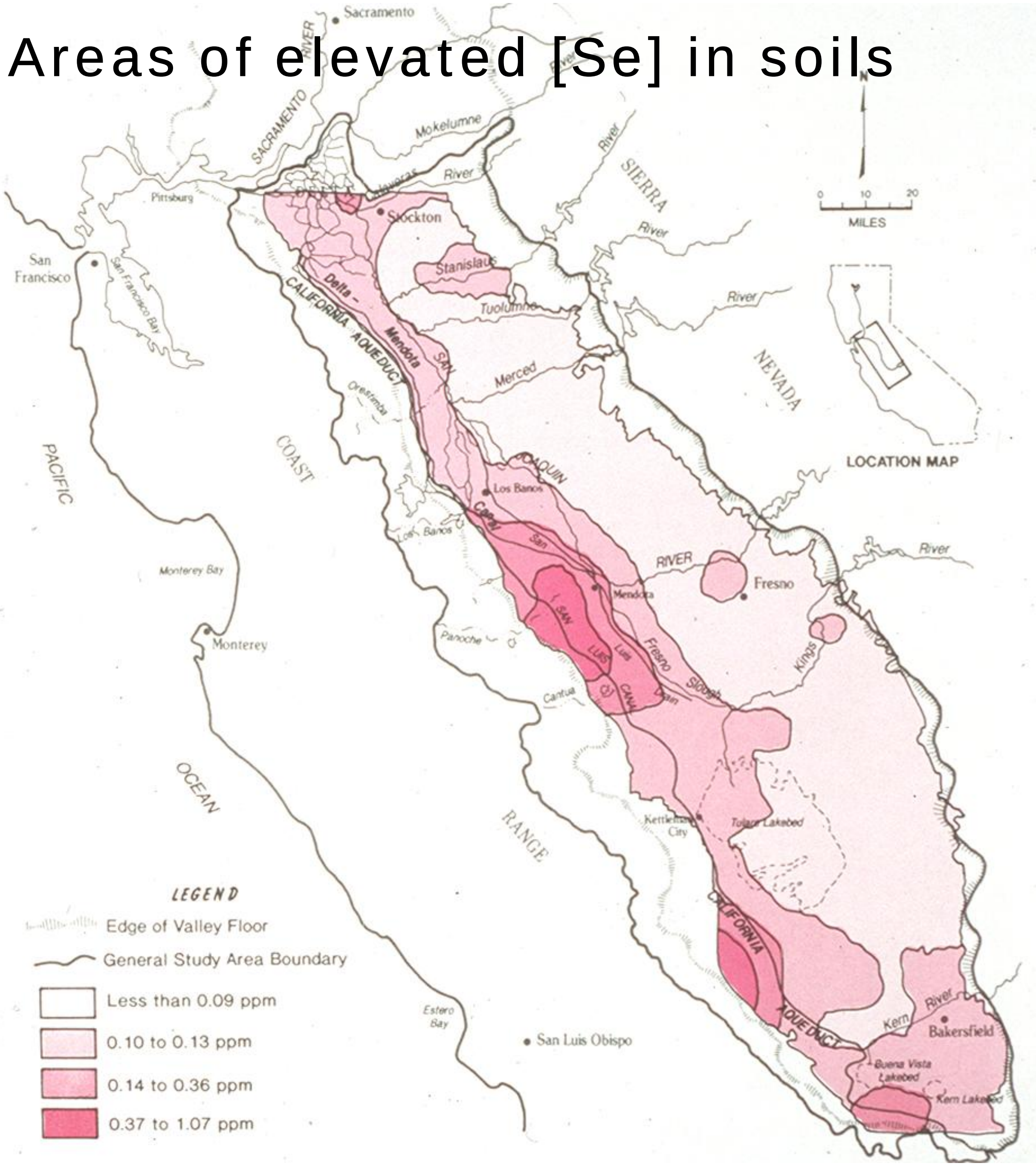
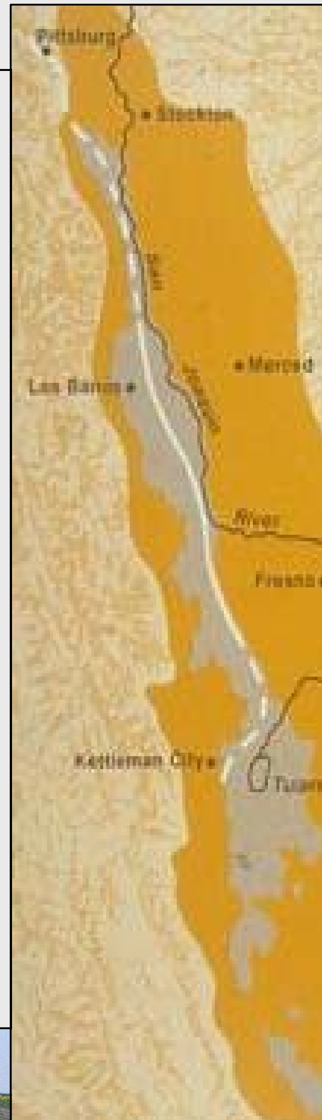
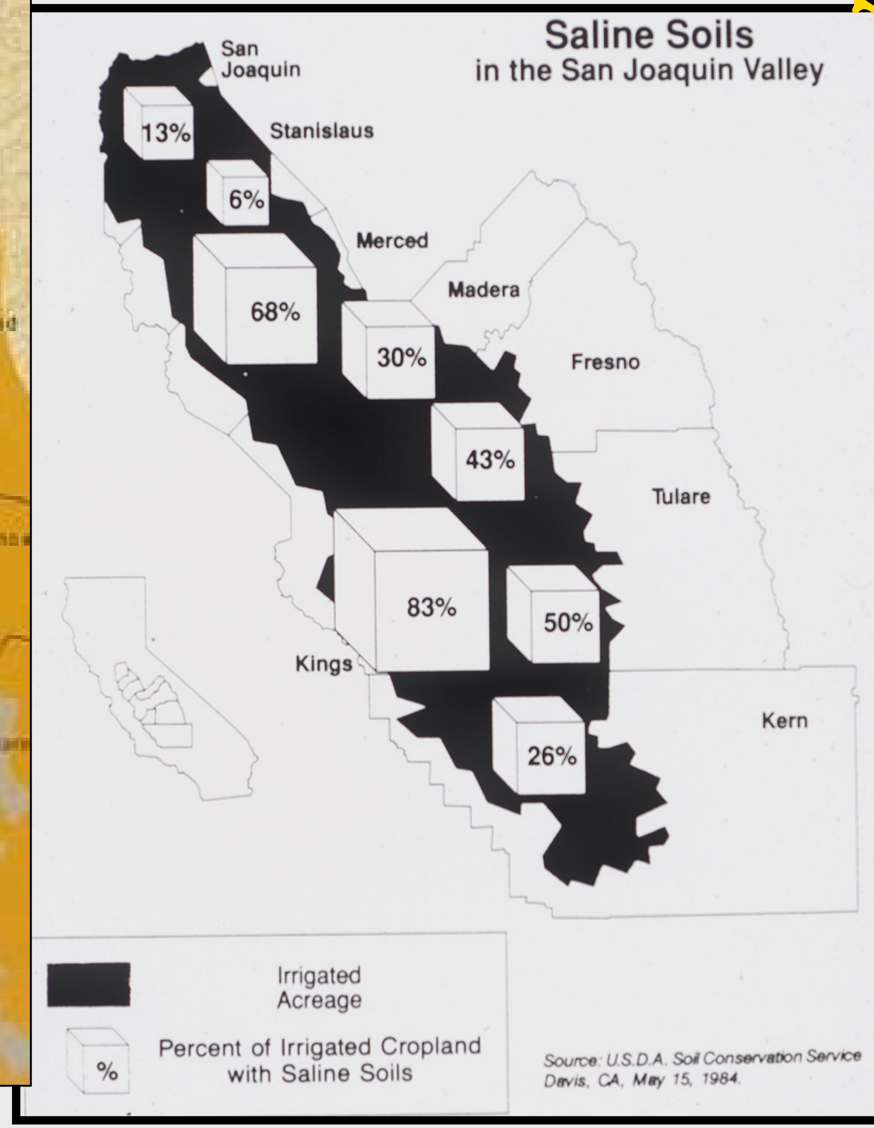
Areas of elevated [Se] in soils



DWR, 1990

Large areas of the western San Joaquin Valley are affected by salinity. When irrigation projects were first constructed, plans were made to construct a master drain for saline water leading to SF Bay. For financial, environmental and political reasons, the drain was only partially constructed, and is not being used.





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Within-valley solutions to the salinity/drainage problem

- Land-retirement
- Waste water treatment (RO)
- Evaporation ponds
- Modification of irrigation and drainage practices
- Reuse of drainage water

Evaporation pond in the San Joaquin Valley

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Biofuels and salinity management in the WSJV

Without conjunctive use of surface water (deliveries) integrated with GW pumping, the consequences of continuing irrigation in the WSJV are clear and largely not reversible. The area of saline high water tables will increase and the quality of GW will decline.

The duration of a conjunctive use strategy could be extended through land retirement, improved irrigation management, and reuse of drainage water for irrigation of salt tolerant crops.

Wichelns and Oster (2006). Ag Water Management. Pg 120-121

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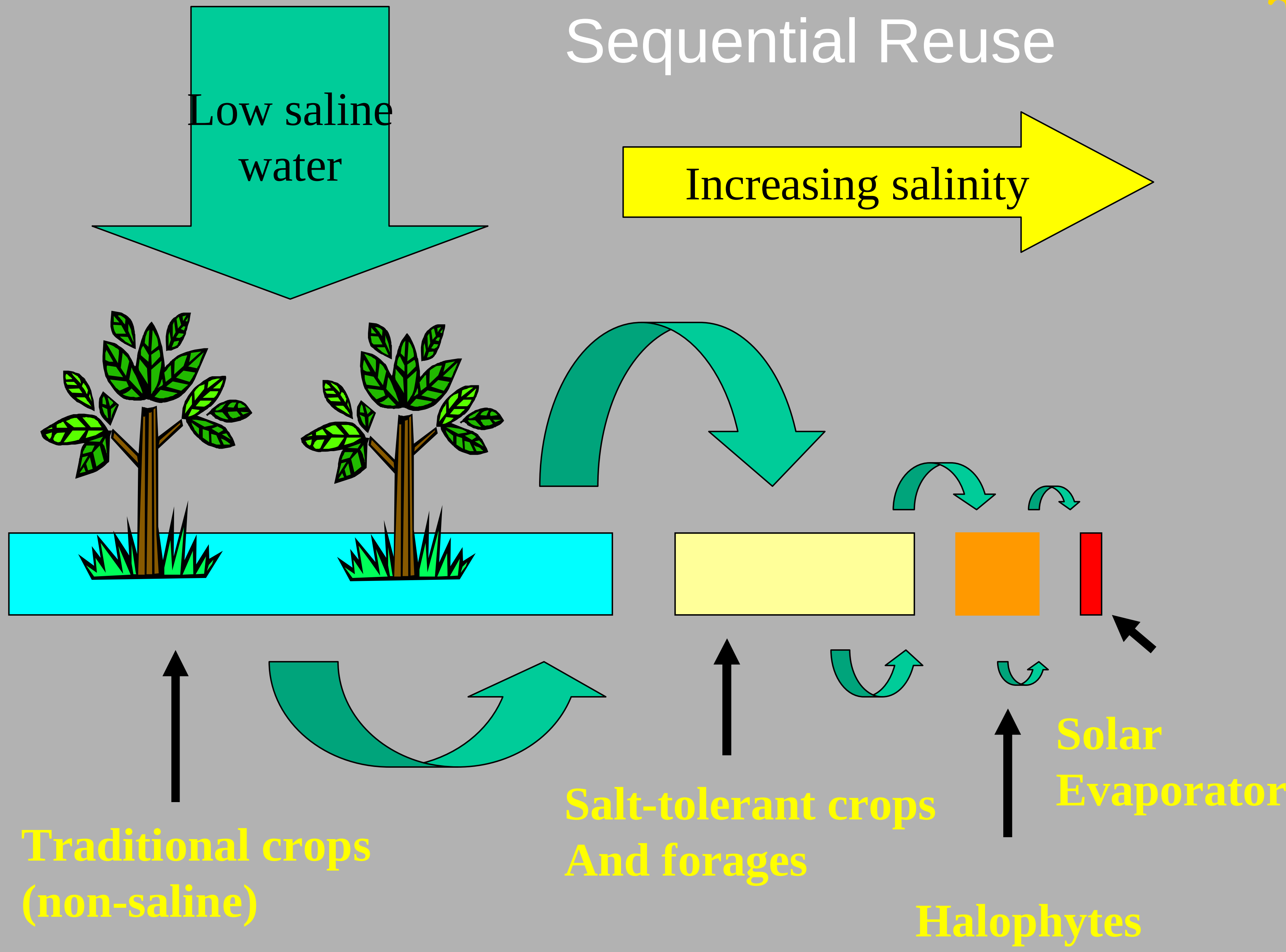
Sequential Reuse



S.Grattan

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Sequential Reuse of Saline Drainage Water/RRR

Sensitive crops

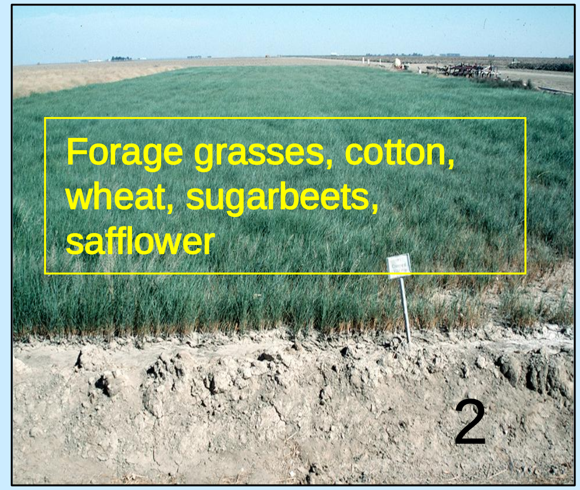
Alfalfa

Tomatoes

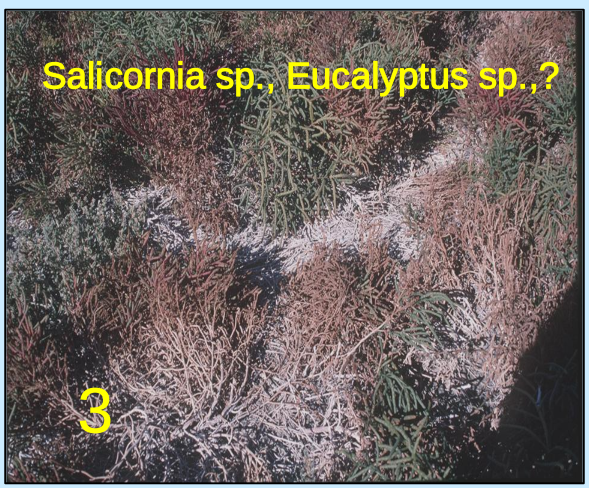
Vegetable crops

1

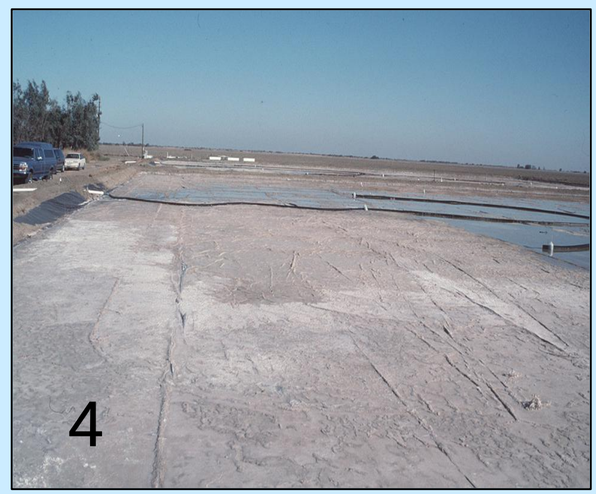
Salt-tolerant crops

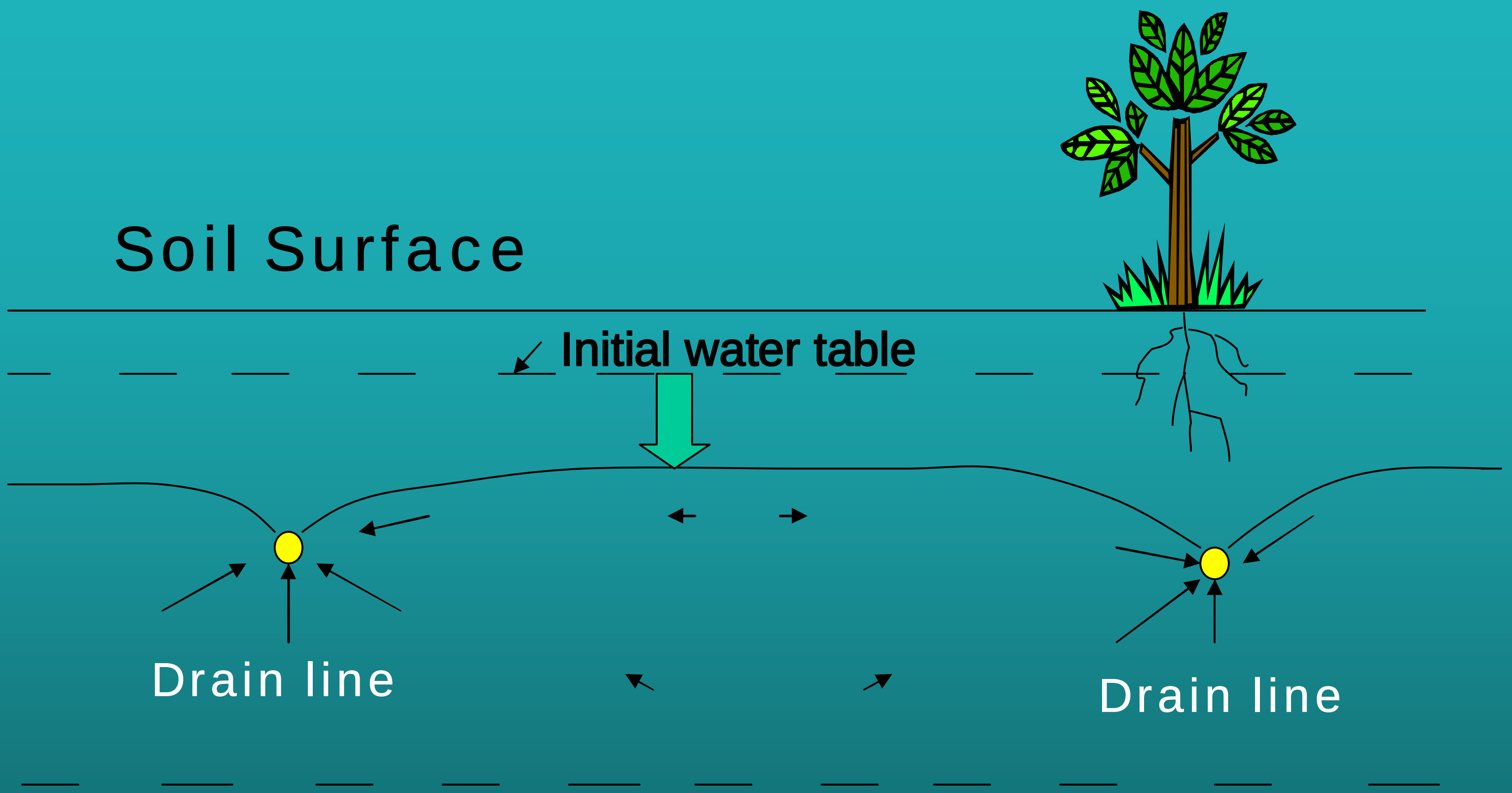


Halophytes



Evaporation





Long travel times for salt to reach drains

S. Grattan

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Simplified regional sequential reuse system:

Using forages and livestock to manage drainage water

Ease of management, Low cost

Use of livestock to add value

Drainage water can be reduced in volume, but salts & Se still must be managed

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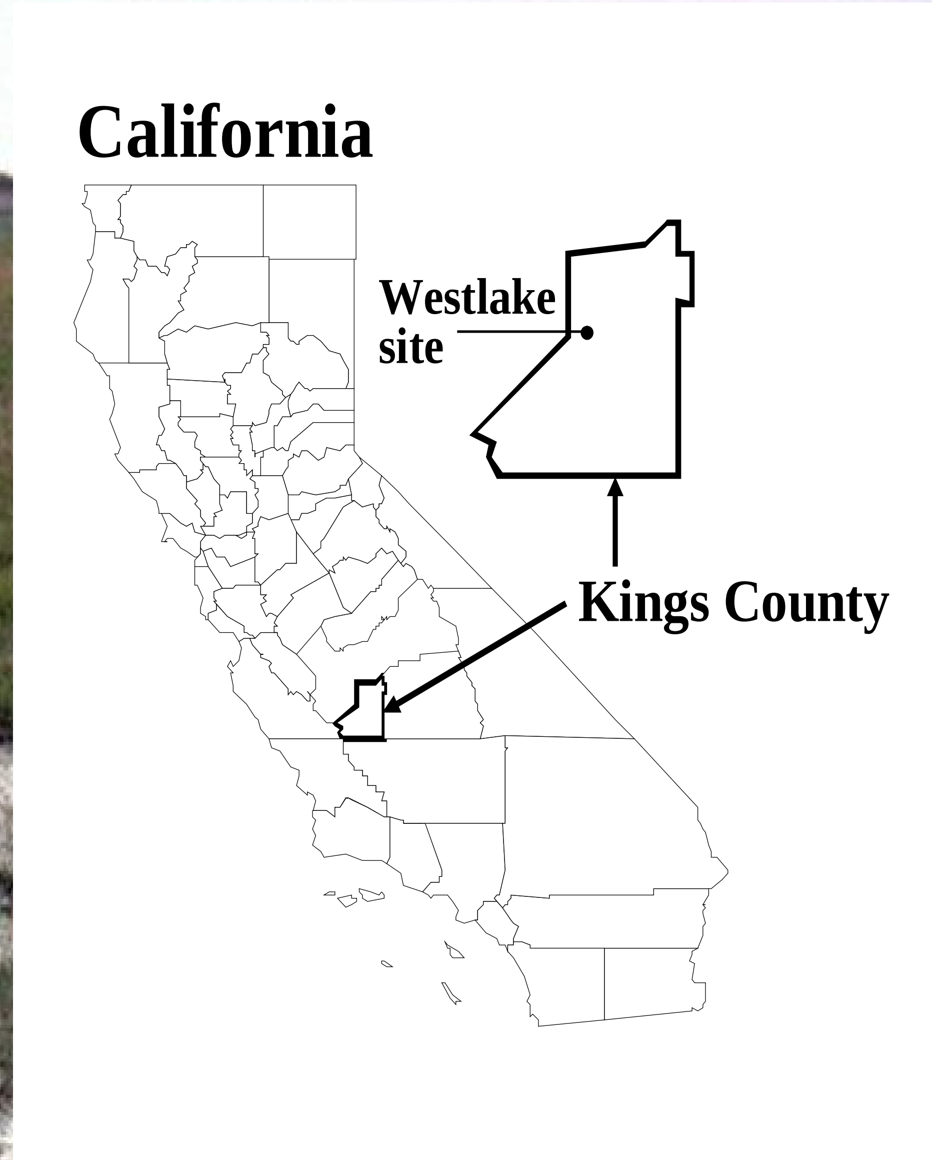
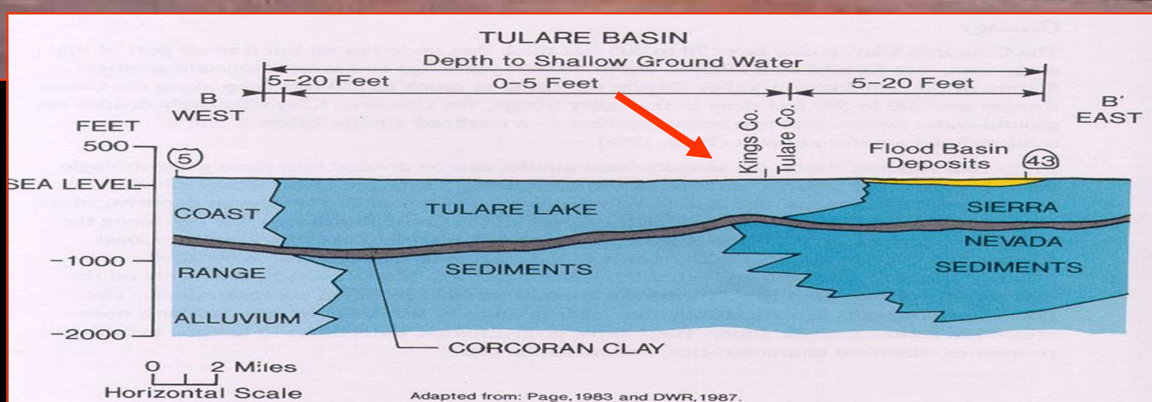
Research site location:

DW reuse for forage production;



Kaffka, Oster, Corwin, Maas, Alonso.



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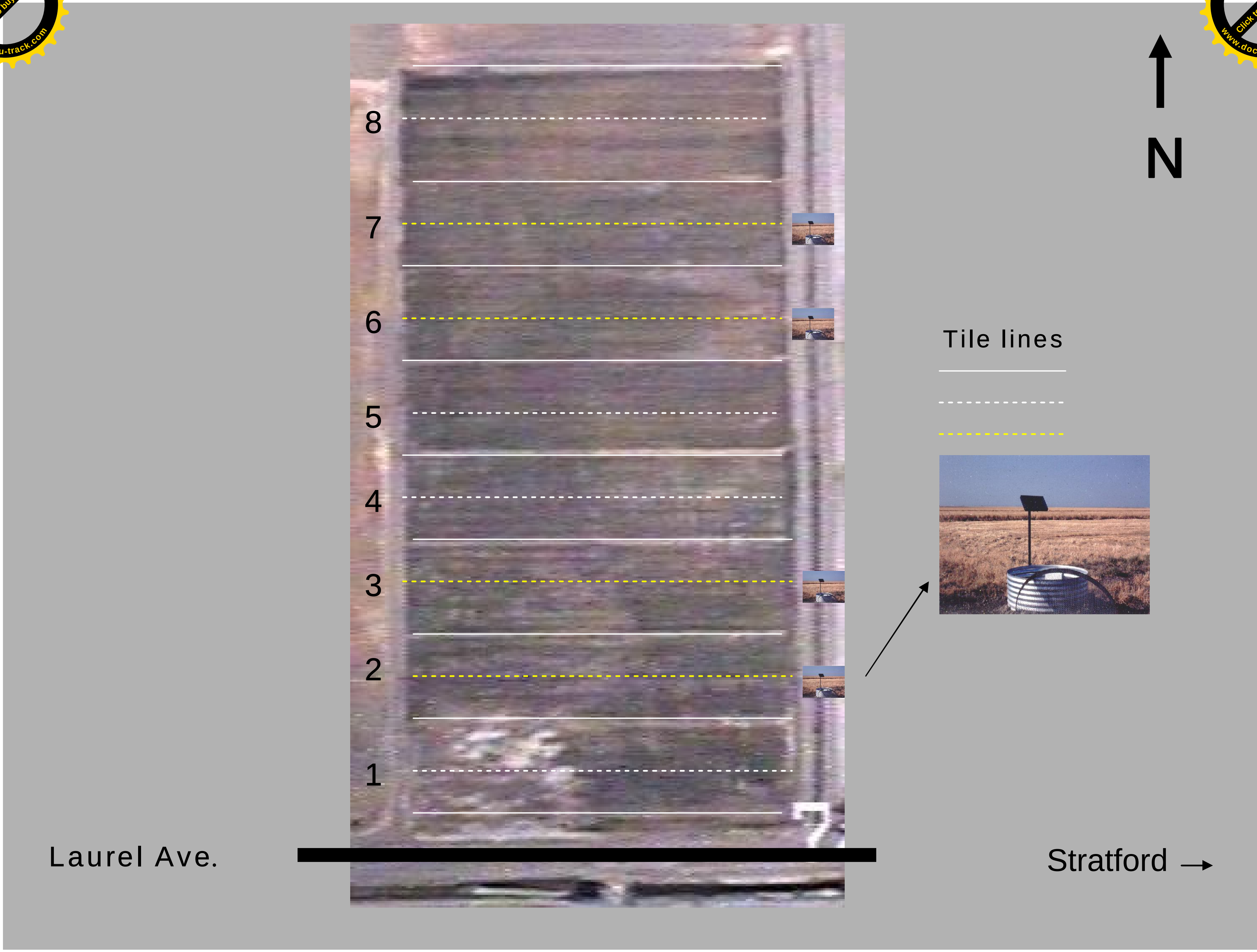

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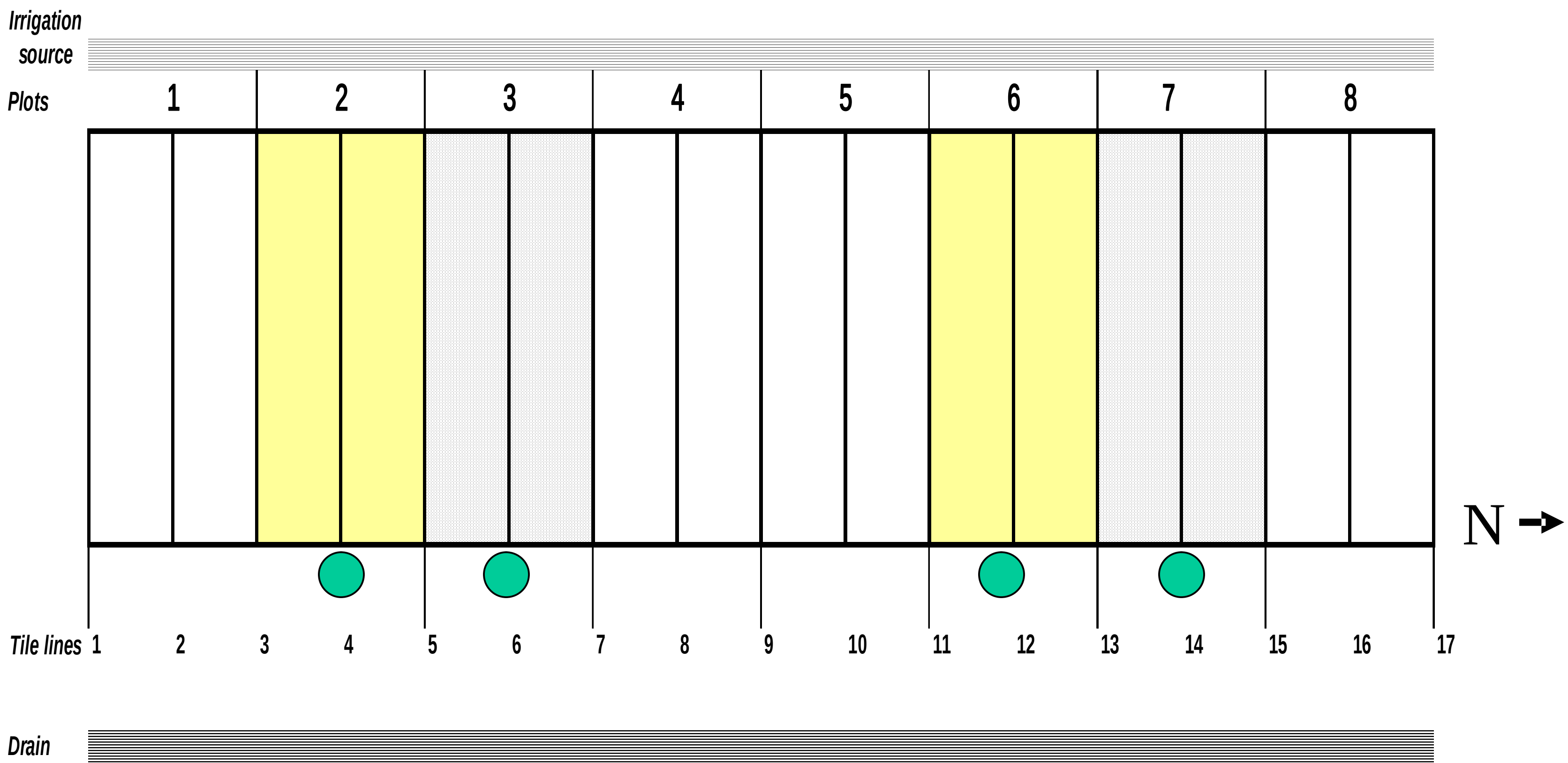
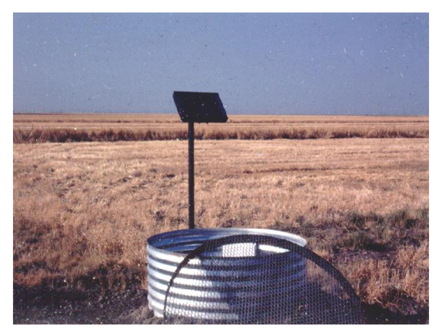
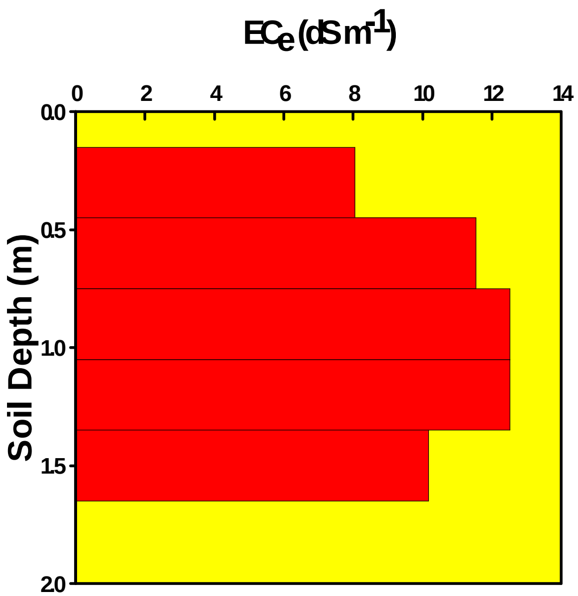


Tile drain and plot layout;
Tile drain monitoring station:



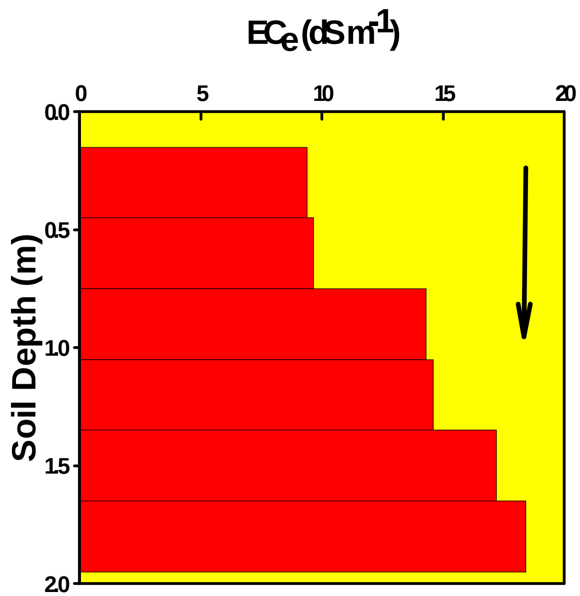
Profile ratios (EMh/EMv)

Uniform,
(no leaching)



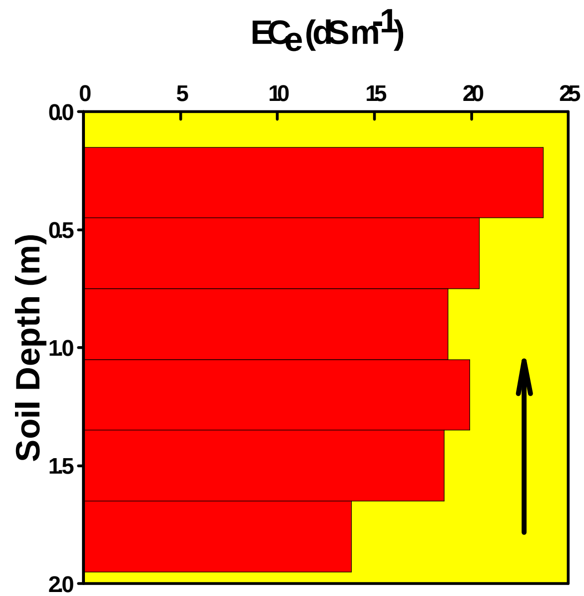
EMh/EMv = 1

Regular,
(leaching is occurring)



EMh/EMv < 1

Inverted,
(salt moves to surface)



EMh/EMv > 1

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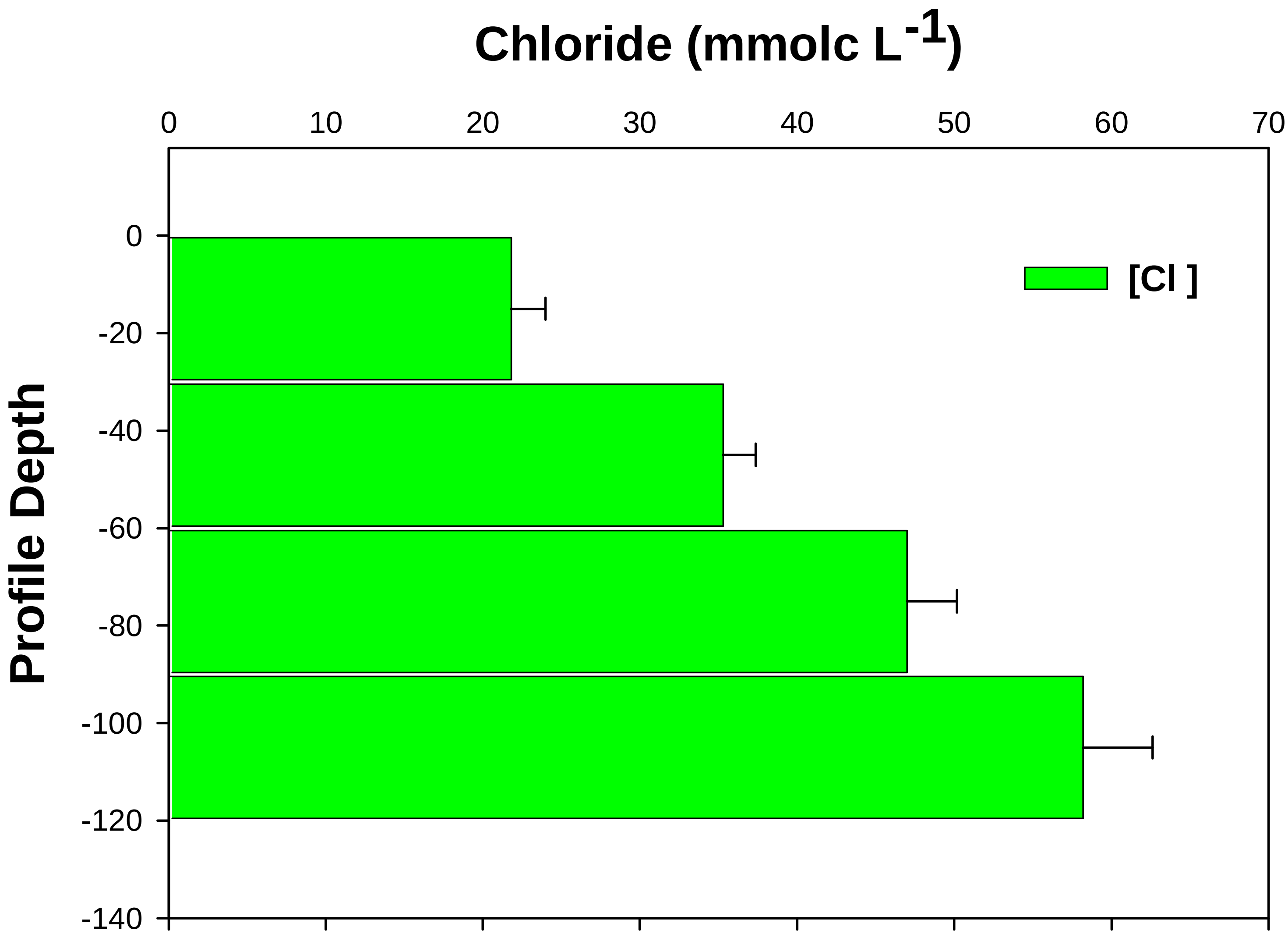

Average [Cl] (mmolc L^{-1}) by depth. August 1999. Error bars are s.e.

Soil and forage sampling locations

Laurel Avenue

12	13	36	37	60	61	84	85	108	109	132	133	156	157	180	181	204	205	228	229	252	253	276	277	300	301	324	325	348	349	372	373
11	14	35	38	59	62	83	86	107	110	131	134	155	158	179	182	203	206	227	230	251	254	275	278	299	302	323	326	347	350	371	374
10	15	34	39	58	63	82	87	106	111	130	135	154	159	178	183	202	207	226	231	250	255	274	279	298	303	322	327	346	351	370	375
9	16	33	40	57	64	81	88	105	112	129	136	153	160	177	184	201	208	225	232	249	256	273	280	297	304	321	328	345	352	369	376
8	17	32	41	56	65	80	89	104	113	128	137	152	161	176	185	200	209	224	233	248	257	272	281	296	305	320	329	344	353	368	377
7	18	31	42	55	66	79	90	103	114	127	138	151	162	175	186	199	210	223	234	247	258	271	282	295	306	319	330	343	354	367	378
6	19	30	43	54	67	78	91	102	115	126	139	150	163	174	187	198	211	222	235	246	259	270	283	294	307	318	331	342	355	366	379
5	20	29	44	53	68	77	92	101	116	125	140	149	164	173	188	197	212	221	236	245	260	269	284	293	308	317	332	341	356	365	380
4	21	28	45	52	69	76	93	100	117	124	141	148	165	172	189	196	213	220	237	244	261	268	285	292	309	316	333	340	357	364	381
3	22	27	46	51	70	75	94	99	118	123	142	147	166	171	190	195	214	219	238	243	262	267	286	291	310	315	334	339	358	363	382
2	23	26	47	50	71	74	95	98	119	122	143	146	167	170	191	194	215	218	239	242	263	266	287	290	311	314	335	338	359	362	383
1	24	25	48	49	72	73	96	97	120	121	144	145	168	169	192	193	216	217	240	241	264	265	288	289	312	313	336	337	360	361	384
Paddock 1				*Paddock 2*				*Paddock 3*				*Paddock 4*				*Paddock 5*				*Paddock 6*				*Paddock 7*				*Paddock 8*			

Forage samples only

Soil + forage samples

N

Pre-grazing condition, summer

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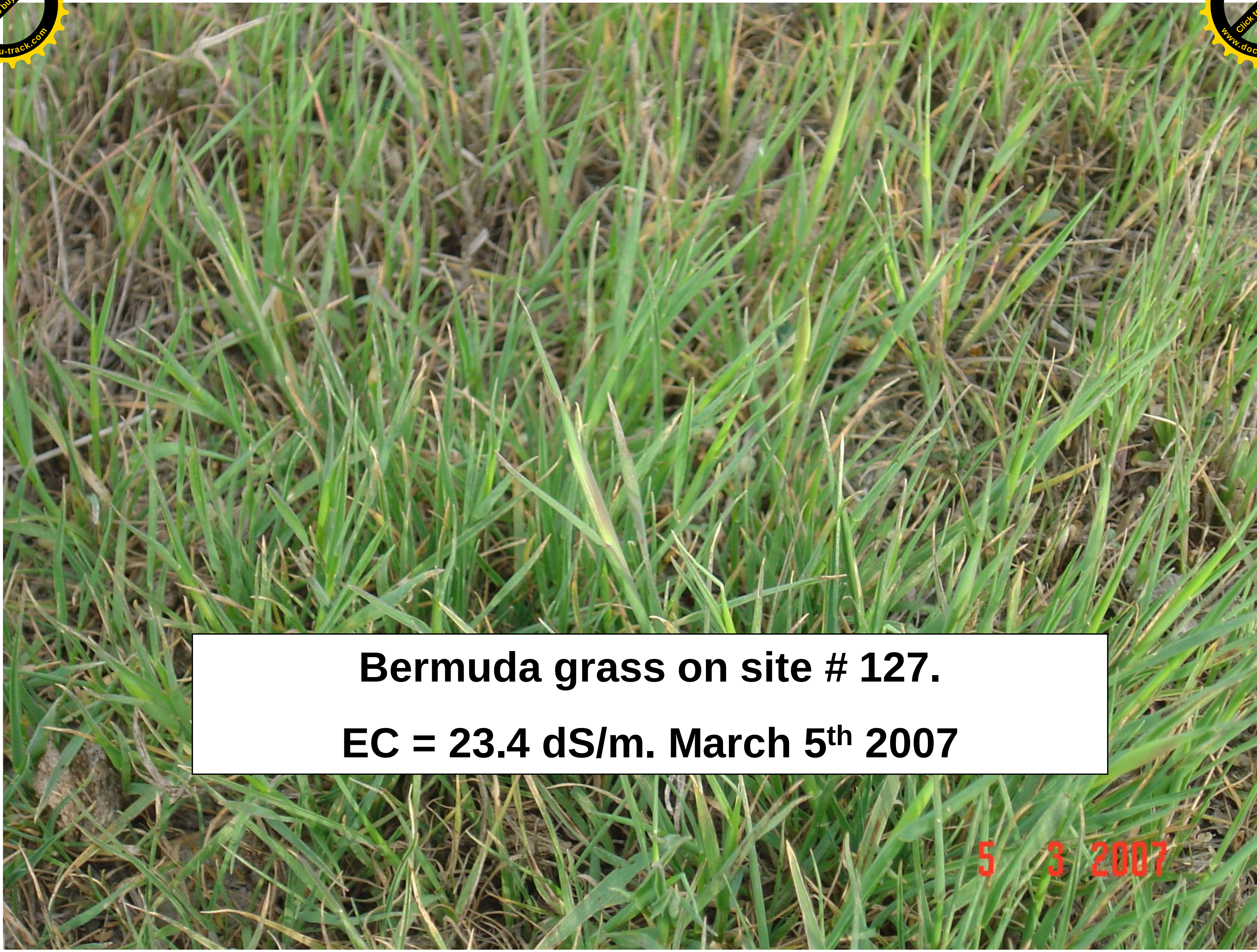

Bermuda grass on site # 127.

EC = 23.4 dS/m. March 5th 2007

Soil sample means at 4 depths (1999/2004)

Profile Depth / Variable	0-0.3m	0.3-0.6	0.6-0.9	0.9-1.2
ECe (dS/m)	13.0/11.4	20.2/17.5	22.5/22.5	25.2/24.3
pH_e	7.61/7.67	7.58/7.87	7.63/8.03	7.57/8.03
SP %	58.8	63.0	59.1	58.7
Cl (mmolc/L)	21.8/18.3	35.3/30.2	47.1/47.1	58.7/55.6
SAR	28.2/23.5	51.4/40.3	59.0/53.4	64.9/57.5
B (mg/L)	17.0/14.2	19.0/19.1	17.5/21.5	17.9/21.7

Corwin et al., 2008

Average of Irrigation Events (2002)

	Irrigation	Drainage	EC_{iw}	EC_{dw}	LF
	mm	*mm*	*dS/m*	*dS/m*	
Ave.	90	2.8	3.6	33.9	0.06
Range	80 - 100	0.23 - 5.9	2.0 – 8.0	30 - 40	0.05 – 0.08

Based on Corwin et al., 2008

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On a high SAR soil, using moderate EC_w irrigation water (2 to 12 dS m^{-1}), no infiltration and drainage problems have been observed where forages have been able to grow during the last nine years. Leaching and reclamation are occurring.

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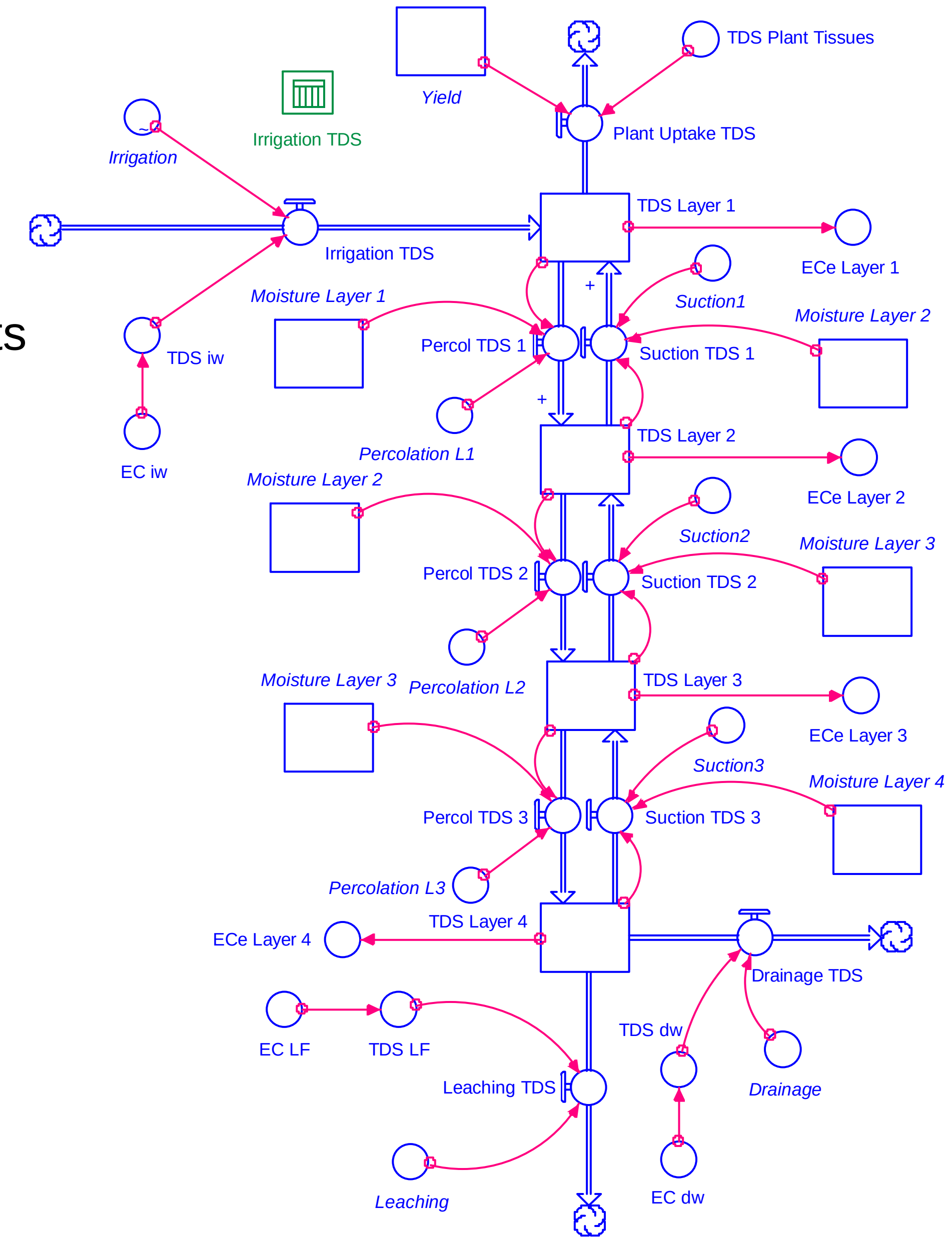
The Model:

Subroutine Water & Salts



Alonso and Kaffka

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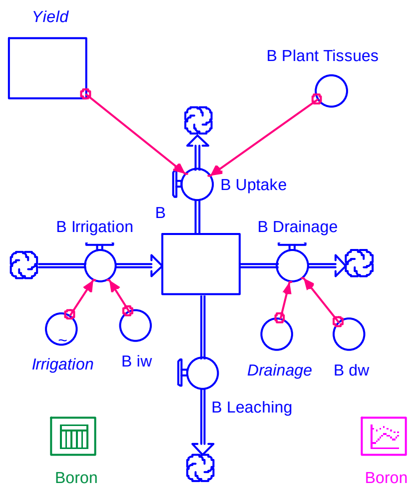
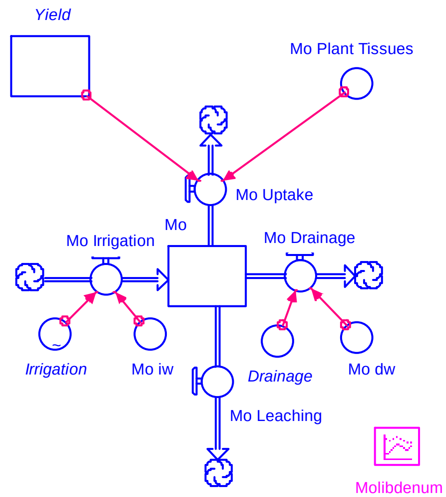
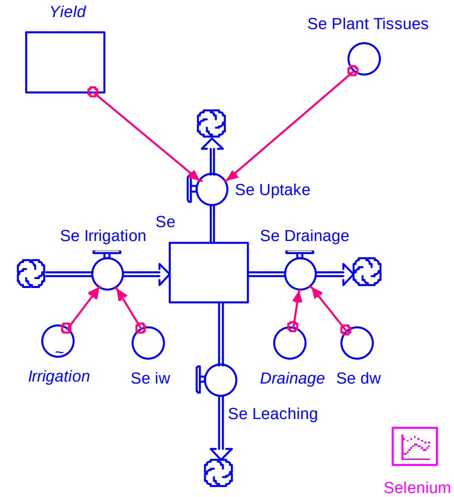
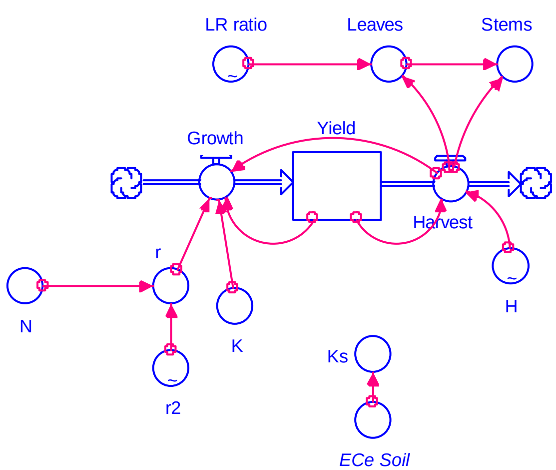
Subroutine Trace Minerals

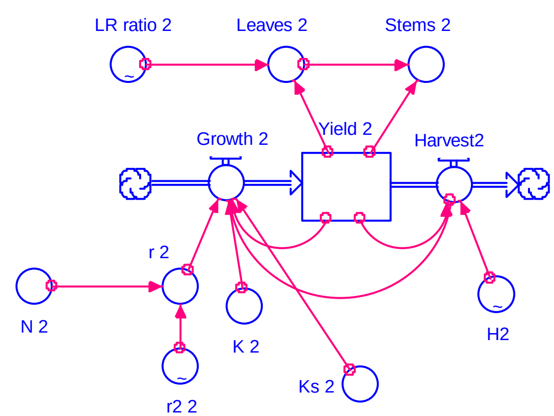






Subroutine Plant Yield





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Drainage water reuse

Advantages:

- Reduces the volume of drainage water for disposal
- Reduces the costs of disposal
- Preserves GW
- Maintains farming area
- Provides positive income?

Disadvantages:

- Accumulation of salts locally
- Accumulation of trace elements (boron, Se, Mo,…)
- Adverse effects on soil physical properties like infiltration and crusting

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Drainage water reuse

- The salinity of shallow drainage water in the western SJV commonly ranges between 4 and 12 dS m^{-1}.
- SO_4 type salts are more common than Cl salts.
- Both of these are favorable circumstances for drainage water reuse.
- Trace elements (Se, Mo, B, others) vary in type and amount by location. These complicate reuse and disposal.

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Retired land in the WSJV, but the land must still be managed

Formerly Broadview Irrigation District

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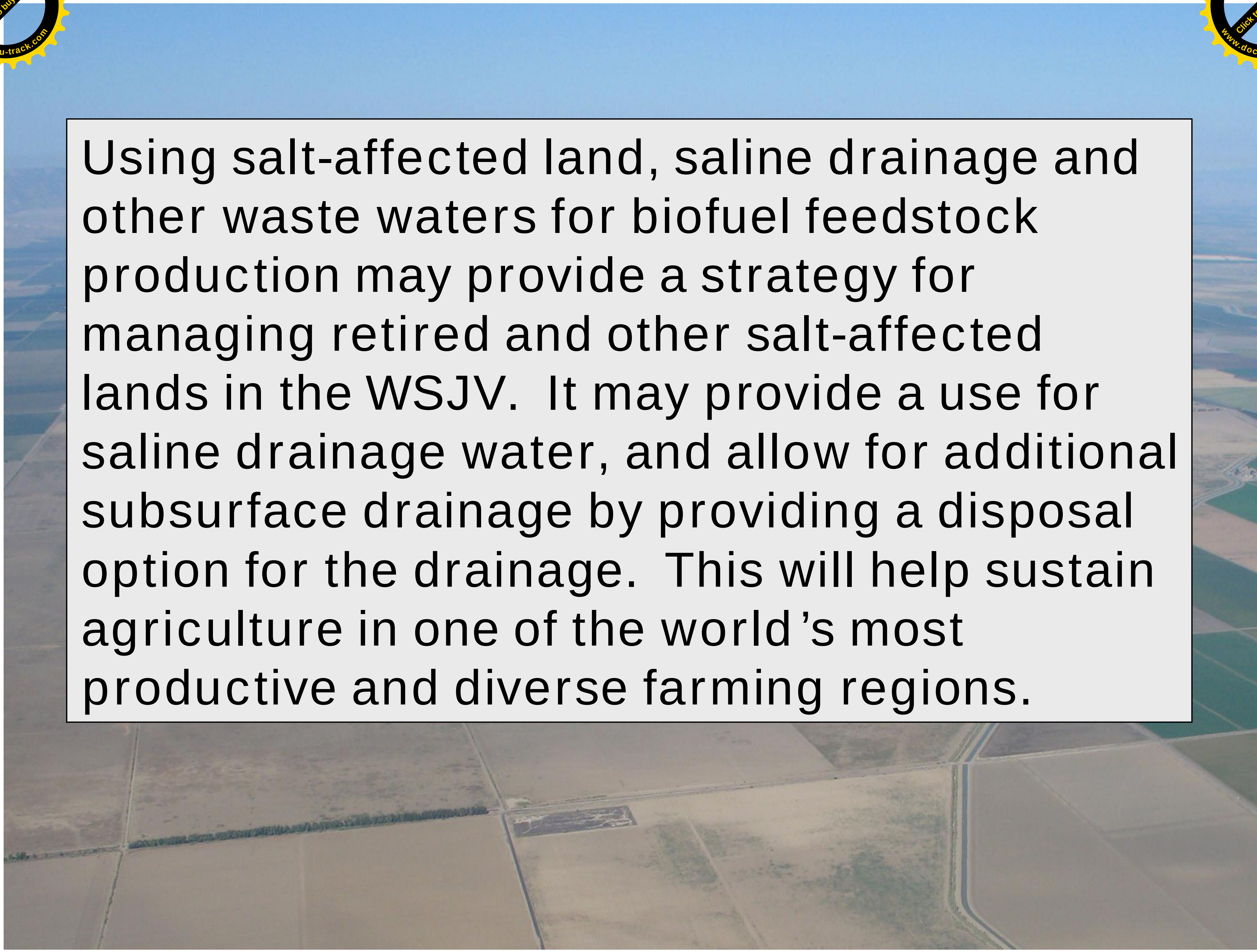
- California has recently adopted a low carbon fuel standard that requires the use of biomass for transportation fuels, and related measures to reduce green house gas (GHG) effects. The use of waste resources is emphasized.

- There is little surplus land and water for biofuel feedstock production in California. Lands in the WSJV and drainage and other waste waters are possible resources for biofuel feedstock production.



Using salt-affected land, saline drainage and other waste waters for biofuel feedstock production may provide a strategy for managing retired and other salt-affected lands in the WSJV. It may provide a use for saline drainage water, and allow for additional subsurface drainage by providing a disposal option for the drainage. This will help sustain agriculture in one of the world's most productive and diverse farming regions.

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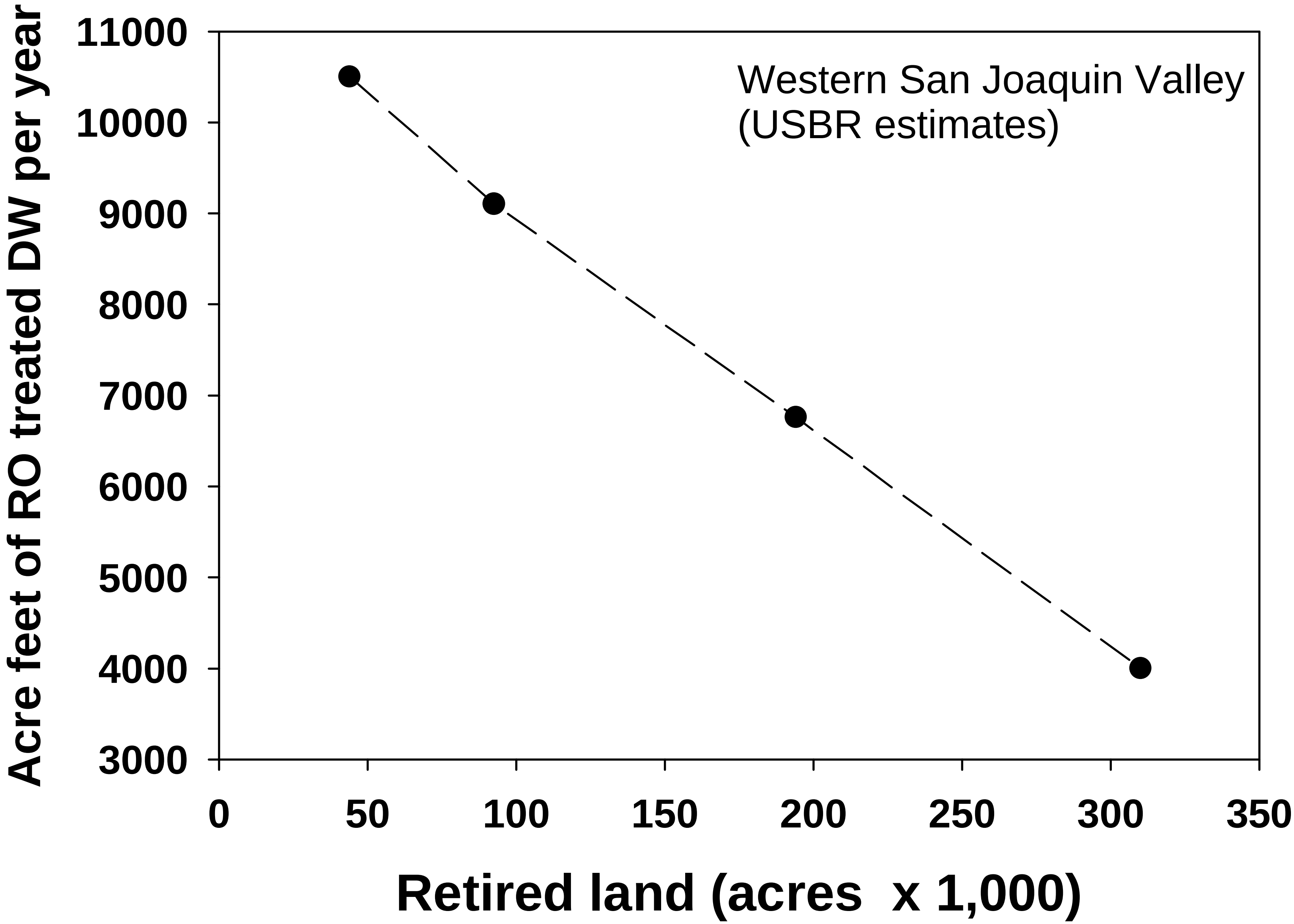
Based on Wichelns and Oster, 2006



USBR cost estimates for in-valley DW management in the WSJV*
(drainage service to 300,000 ac of land)

Project item	In-valley with land retirement	
	GW quality [Se> 50 ug/L]	Impaired Drainage Retirement
Evap. Ponds needed	yes	yes
RO facilities needed	yes	yes
Area retired (ac)	92,500	308,000
Vol of DW treated for Se	9,100 ac ft	4,000 ac ft
Investment costs (x 1,000)	$825,000**	$945,000**
Cost per ac	$2,180	$2,490
Annual tmt cost (x 1,000)	$21,230	$11,693
Cost per ac	$56	$31

*From Wichelns and Oster, 2006/**does not include on-farm drainage systems

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Biofuels and salinity management in the WSJV

The high cost of installing and operating the DW disposal options examined by USBR and the costs of installing on-farm subsurface DW systems motivate consideration of complex, on-farm DW management systems.

In addition, uncertainty regarding project cost overruns and exceedances of environmental standards might be smaller when farmers manage, reuse and dispose of DW within their farming operations.

Wichelns and Oster (2006). Ag Water Management. Pg 123

(+) Advantages---Disadvantages (-)

+ $ from fuel (or power) sales will help fund Se clean-up
+ Alternative sources of fuel or power are produced with a low CO_2 footprint
+ Se cleanup is made simpler
+ Less farmland is retired, retaining income and reducing the cost of salinity management in the WSJV
+ The rate of saline contamination of GW in the WSJV is reduced, sustaining agriculture and GW quality

- Se enriched water is applied to land where some contamination of terrestrial wildlife may occur
- Se is concentrated on small areas of land in greater amounts, leading to potential contamination of local GW supply
- Se enriched ash or residues must be handled in an environmentally safe manner; some Se emissions to the atmosphere may occur

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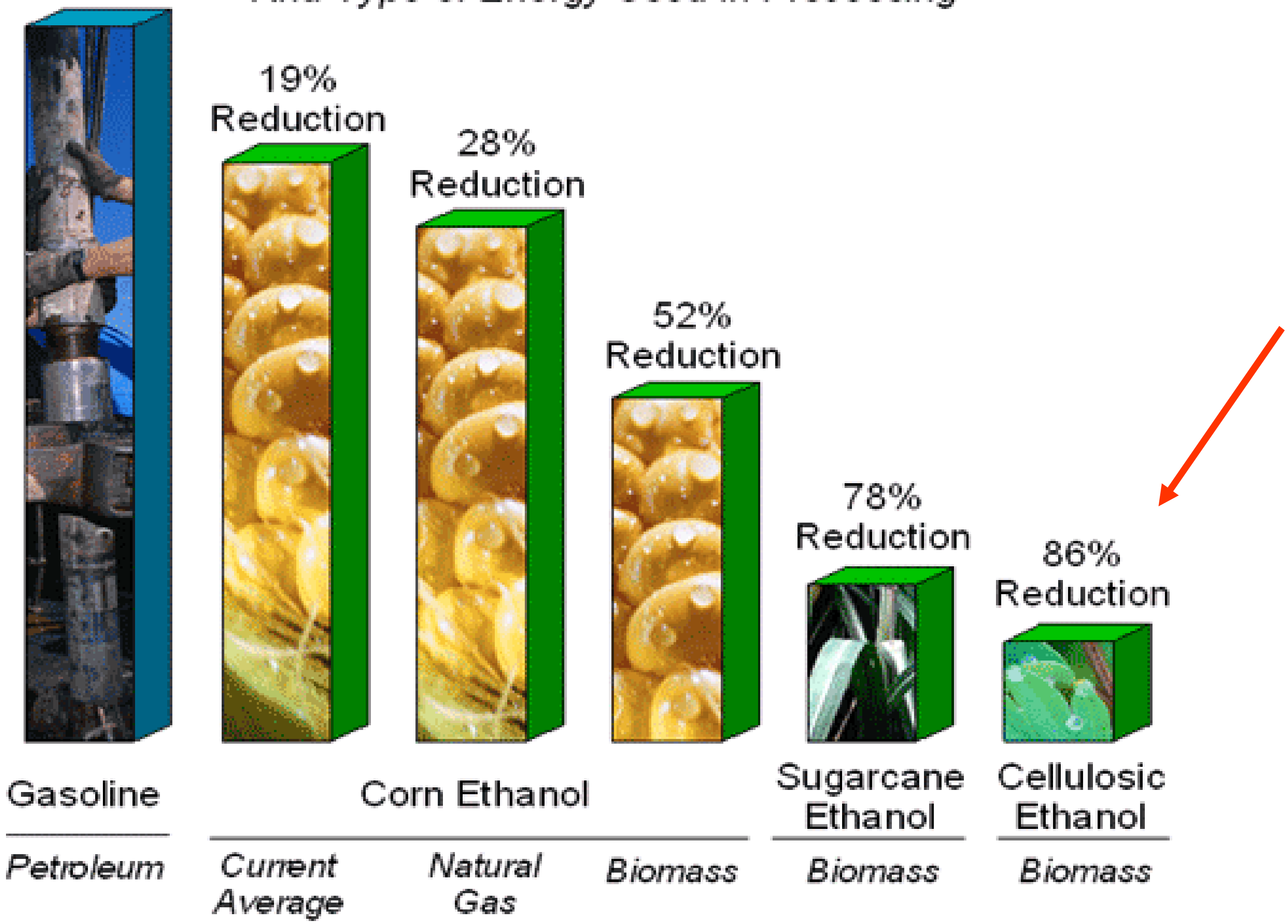
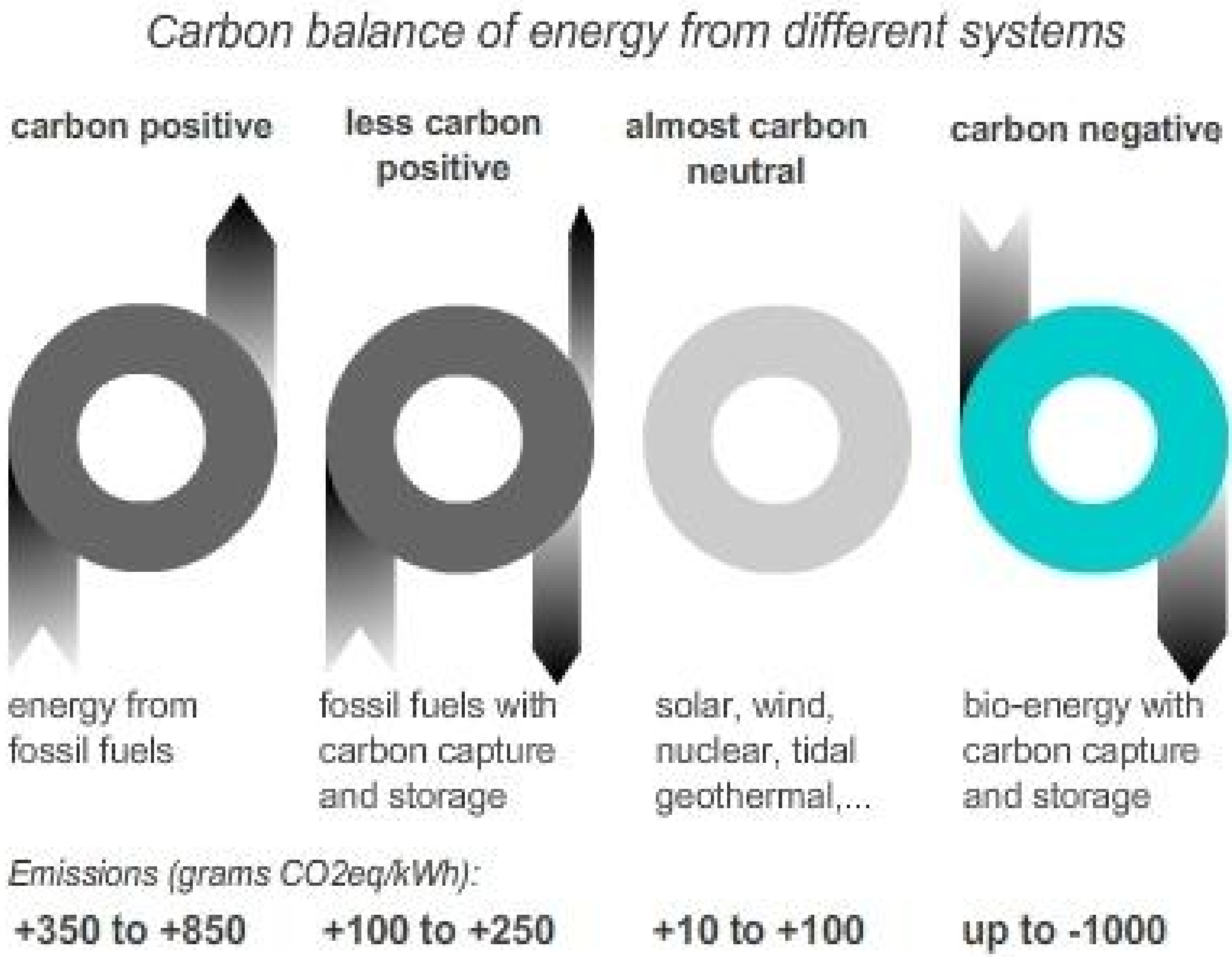
Greenhouse Gas Emissions by Transportation Fuel

And Type of Energy Used in Processing



Sources: Wang et al, *Environ. Research Letters*, May 2007; Wang et al, *Life-Cycle Energy Use and GHG Implications of Brazilian Sugarcane Ethanol Simulated with GREET Model*, Dec. 2007



Source: Biopact-carbon

Energy Return On Investment: the ratio of energy in a L of biofuel to the nonrenewable energy required to make it.

Source	EROI
Older US Oil	100:1
Current US Oil	15:1
Corn Ethanol	1.3:1
Brazilian sugar cane	8-9:1 (12:1)
Biodiesel (soy)	3:1
Cellulosic sources (assumes mature technology)	5-12:1

Data: various sources

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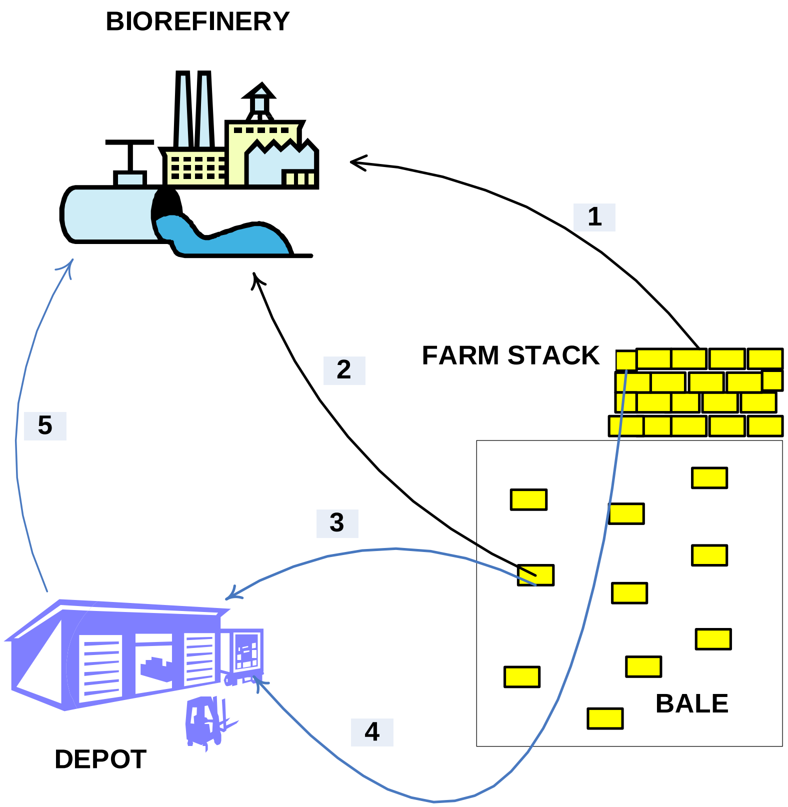
USDA-ARS Idaho



Issues

- Agricultural practices
- Agronomic issues
- Yields and acreage
- Infrastructure restrictions/regulations
- Economics
- Climate
- Business Model

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Performance Metrics:

- **Efficiency ($/hr)**
- **Equipment Capacity (ton/hr)**
- **Biomass Quality ($/ton)**

Biomass Production
- Agricultural Resources:
  - Crop Residues
  - Energy Crops
- Forest Resources:
  - Logging Residues
  - Harvested for Energy

Harvest and Collection → Storage → Preprocessing → Transportation → Handling and Queuing at the Biorefinery → Feedstock Interface Boundary

Harvest and Collection:
- Equipment Capacity
- Compositional Impacts
- Pretreatment Impacts

Storage:
- Shrinkage
- Compositional Impacts
- Pretreatment Impacts
- Soluble Sugar Capture

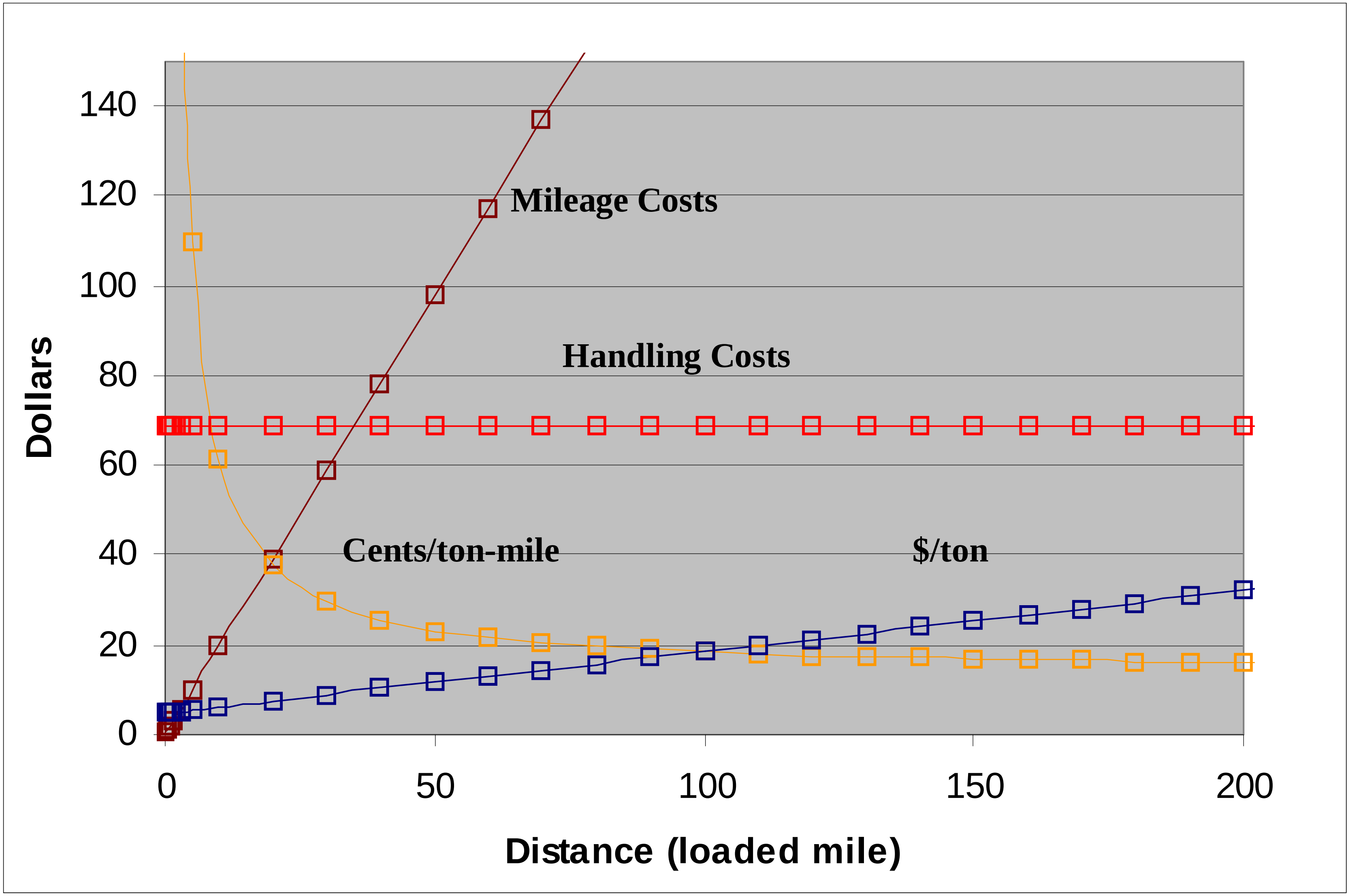
Preprocessing:
- Equipment Capacity
- Material Bulk Density
- Compositional Impacts
- Pretreatment Impacts

Transportation:
- Truck Capacity
- Loading compaction
- Loading efficiencies

Handling and Queuing at the Biorefinery:
- Handling efficiencies
- Handling compaction
- Material Bulk Properties

Conversion Pathway's Reactors:
- Agricultural Residues
- Energy Crops
- Forest Products

USDA/ARS-Idaho



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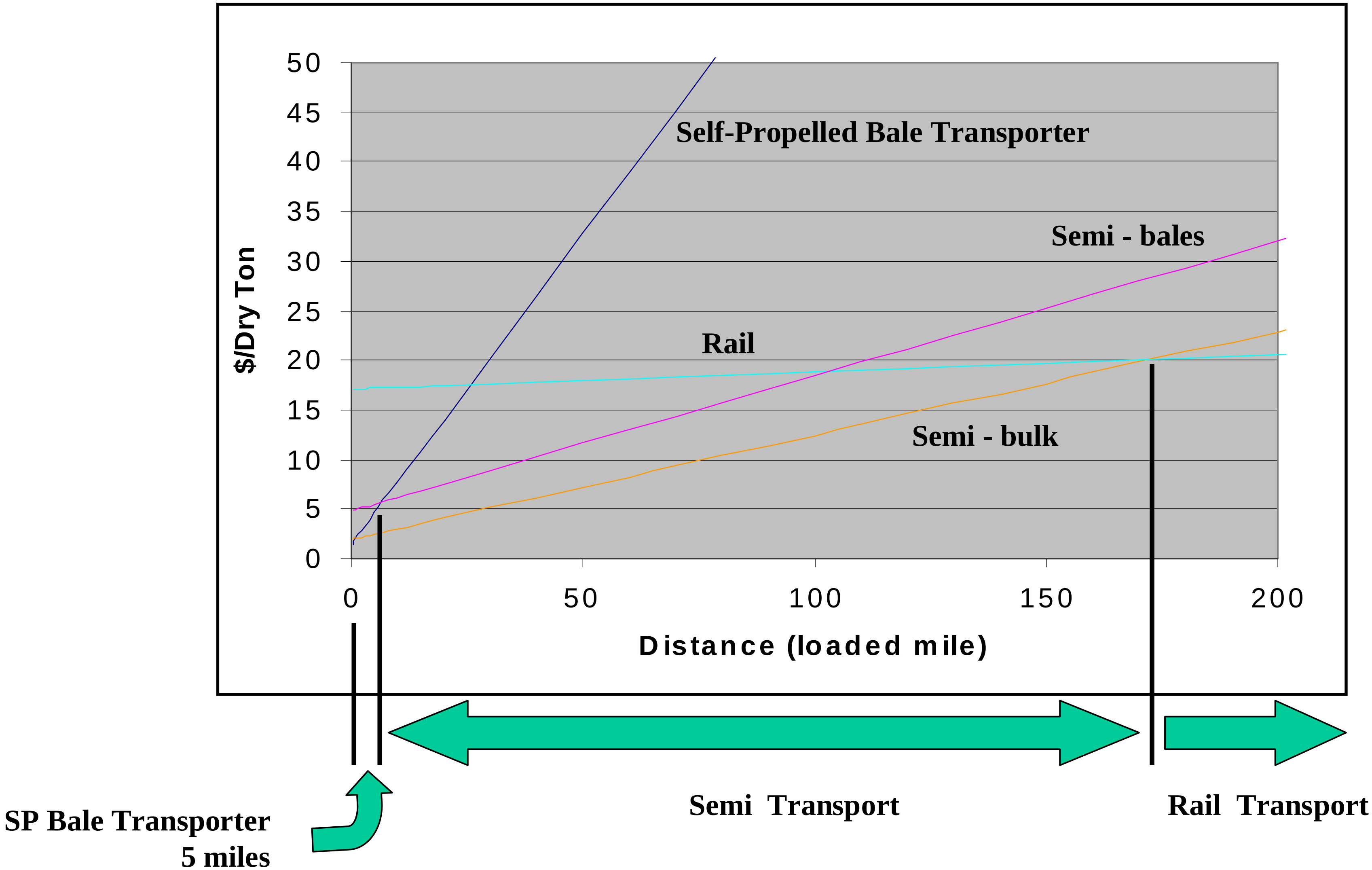

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Location	Installed Capital ($/dry ton)	Total Engineering Costs ($/dry ton)	Grower Payment Costs ($/dry ton)
Idaho Straw	$88.65	$33.48	$10.00
Kansas Straw	$75.48	$46.17	$10.00
Kansas Stover	$110.37	$57.22	$10.00
Virginia Straw	$173.90	$61.87	$10.00
Virginia Stover	$175.58	$65.47	$10.00

Economies of scale:

Virginia: 125,000dt/yr;

Kansas: 255,000 dt/yr;

Idaho: 800,000 dry ton/yr

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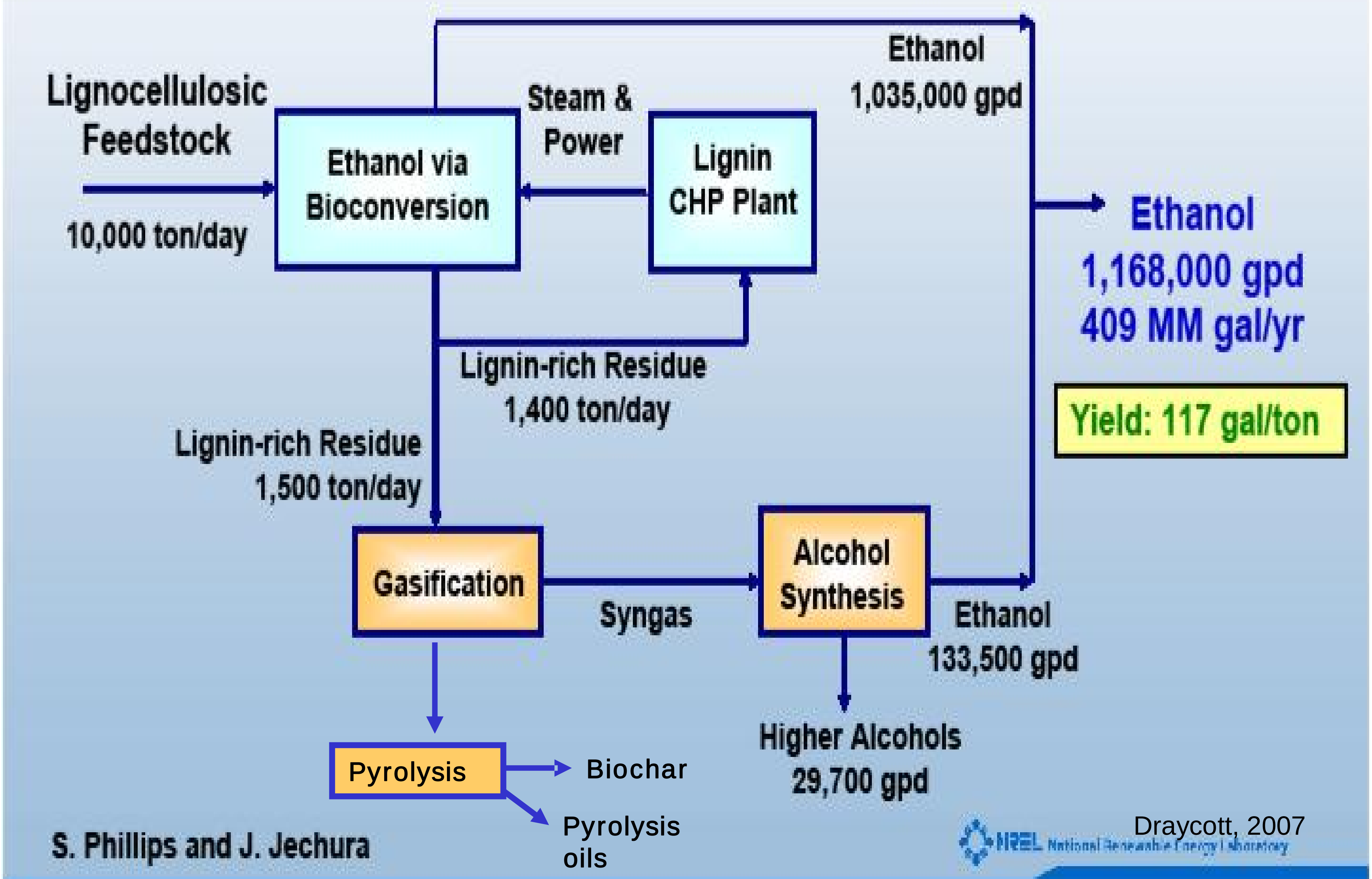
Potential future cellulosic biorefinery



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Bio-char

Typical product yields (DM basis) by different models of combustion

	Temperature	Residence Time	Liquid %	Char/Ash %	Gas %
Fast Pyrolysis	**Moderate**	**Short**	**75**	**12**	**13**
Carbonization	**Low**	**Very Long**	**30**	**35**	**35**
Gasification	**High**	**Long**	**5**	**10**	**85**

Source: Bridgwater 2003. Renewable fuels and chemicals by thermal processing of biomass. Chemical Engineering Journal 91, 87-102.

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Surface area of hay fields required under different land retirement alternatives*

Land Retirement alternative	Drainage Volume	AVG ETc Pasture	Hay fields Required
ac	acft/y	acft/ac/y**	ac
Current	**82,362**	**5.16**	**15,968**
100,000	**76,611**	**5.16**	**14,853**
200,000	**58,875**	**5.16**	**11,414**
300,000	**37,960**	**5.16**	**7,359**

Source: *Presser & Schwarzbach, 2008. Technical Analysis of In-Valley Drainage management Strategies for the Western San Joaquin Valley. USGS 1210, 37 p.

**Alonso and Kaffka, in prep.

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Assumptions:

N-NO3 in DW mg/l	N Fertilization lb/ac	Soil Salinity dS/m	DW Salinity dS/m	Potential Yield ton/ha
6 (84)	200	< 12	10 +/- 1	12

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Trace minerals recovered in the biomass produced:

Land Retirement alternative ac	TOTAL Biomass ton DM	B in TOT Biomass lb	Mo in TOT Biomass lb	Se in TOT Biomass lb
Current	81,500	44,000	258	448
100,000	75,809	40,928	240	417
200,000	58,259	31,453	185	320
300,000	37,563	20,279	119	207

Source: Suyama et al 2007. Forage yield and quality under irrigation with saline-sodic drainage water: Greenhouse evaluation. Agricultural Water Management 88, 159-172.

Assumes drainage service provided to affected acres and DW derives from service.

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Se emissions and Se in ash from the combustion of residual biomass from ethanol production. We assume that power from combustion of ethanol residue is used to manufacture ethanol. Some Se in waste water is not yet accounted.

Land Retirement alternatives	TOTAL Biomass	Ethanol Potential[1]	Se Particulate Matter[2]	Se Exhaust Gas[3]	Se Bed & Cyclone[4]
ac	ton DM	gal	lb/yr	lb	lb
Current	81,500	9,840,100	318	81	49
100,000	75,809	9,153,000	296	75	46
200,000	58,259	7,035,000	228	58	35
300,000	37,563	4,535,229	147	37	23

NOTES

1: 117 gal/ton DM

2: 71%*

3:18%*

4: 11%*

Source: Williams, R.B. California Biomass and Biofuel Production Potential: TIAX Consultant Report. *In Review. D. Draycott, NREL-2007, CBC website*

**Happ et al., 1991. Emission of Se in the combustion products of agro-forestry biomass. Trans ASAE, Alburquerque, NM*

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Non-gas combustion product yields for different land treatment alternatives:

Land Retirement	Fast Pyrolysis		Gasification	
alternative	Liquid	Bio-Char	Liquids, Higher alcohols/ethanol	Ash
ac	tons	tons	tons	tons
Current	63,078	10,092	4,205	8,410
100,000	58,673	9,388	3,912	7,823
200,000	45,090	7,214	3,006	6,012
300,000	29,072	4,652	1,938	3,876

Biofuels and salinity in the WSJV

- An overview of the salinity drainage problem
- DW reuse for forage production
- Economic and environmental costs of salinity and Se management
- Conversion of biomass to energy (ethanol and electricity)
- AB118 salinity standards

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AB 118 Sustainability Criteria: DW reuse for biofuel feedstock production

Goal	Characteristic	Evaluation
1. Climate Change: is there a substantial reduction in GHGs?	(C1) Does LCA analysis show a reduction for both direct and indirect GHG effects?	Yes, direct effects are positive, reduces ILUC effects elsewhere
2. Natural Resource Use/Environmental Protection	(C2) Use of waste streams for feed stocks ?	Yes, waste water and idled land are used.
	(C3) More efficient use of of natural resources, less environmental damage than petroleum and agricultural baselines?	Yes, some of the negative con-sequences of irrigation are reduced, pro-ductive farming is sustained in WSJV, Se is better managed.

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AB 118 Sustainability Criteria: DW reuse for biofuel feedstock production

Goal	Characteristic	Evaluation
2. Natural Resource Use/Environmental Protection	(C5) BMPs used?	Yes, in so far as they can be determined.
	(C6) Energy crop uniquely (or well?) suited for California ?	Yes, this feedstock production system takes advantage of special farming conditions in CA.
	(C7) Feedstock originates from land used for agriculture or newly converted land?	Produces crops on idled farm land that must be managed at great public expense and with adverse environmental consequences, including ILUC effects.

AB 118 Sustainability Criteria: DW reuse for biofuel feedstock production

Goal	Characteristic	Evaluation
2. Natural Resource Use/Environmental Protection	(C8) Is renewable energy used for production, processing, etc.?	Yes. Ethanol process residues are used to power the manufacturing process
	(C9) Will project create measurable benefits for environment ?	Yes. Reduces contamination of GW in the WSJV, extends
3. Certified Sustainability Practices	(C10) Is the feedstock certified as sustainable? How?	No existing standard, still to be determined via research and monitoring.

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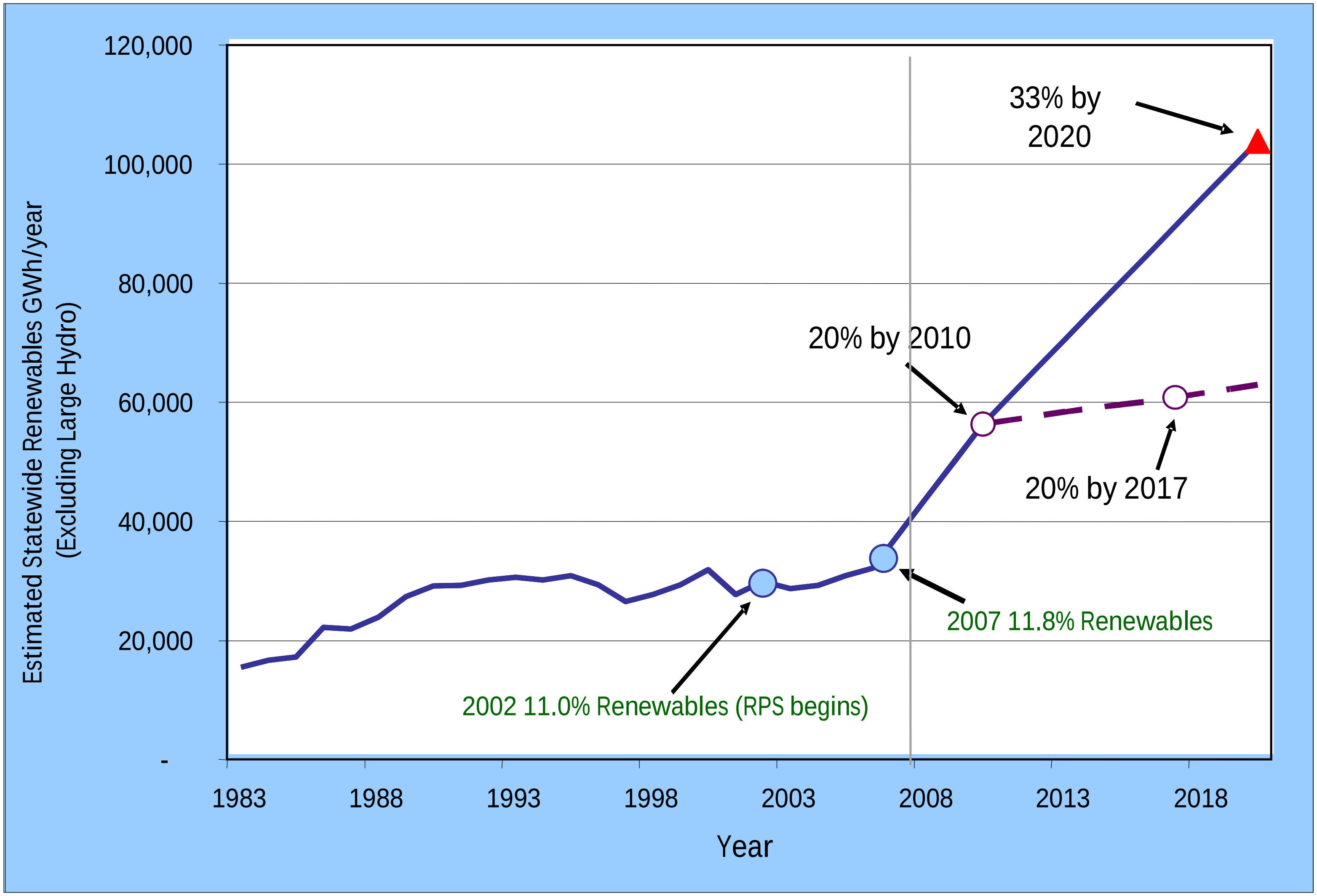
AB 118 Sustainability Criteria: DW reuse for biofuel feedstock production

Goal	Characteristic	Evaluation
4. Minimizes the risk of unintended consequences?	(C12) Creates localized economic benefits for disadvantaged populations, including new jobs?	Yes, new farming and bio-refinery jobs will be created.
	(C12) Avoids localized environmental harm, especially affecting disadvantaged populations?	Some uncertainty around air emissions from the combustion (gasification) of residues in the ethanol production process. Quantitatively small, but technology is unproven. Some terrestrial exposure to wildlife. Likely manageable.
Overall assessment	More positive than negative effects?	Yes

California's Renewable Energy Goals



Oil production from tar sands in Alberta

An alternative to biomass use for energy

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Biofuels and Salinity Management in the Western San Joaquin Valley

- DW reuse for cellulosic biomass and ethanol production is one of the lowest cost management options for salinity and Se management in the WSJV.
- It offers the potential to preserve agricultural production to the greatest extent while minimizing the amount and rate of salinization of GW compared to present alternatives.
- Se will be managed and disposed largely as ash or bio-char from bio-energy production, while providing income from bio-fuel sales to subsidize management and disposal.
- Other alternatives have only large direct public costs and indirect financial losses due to retirement of farmland.
- GHG reduction will be positive because waste resources are used, including nutrients in GW.
- Compared to alternatives, fewer acres of farmland will be retired with corresponding ILUC effects elsewhere in the world to replace lost food production from the WSJV.
- AB118 standards seem to largely support this option but further analysis is required.

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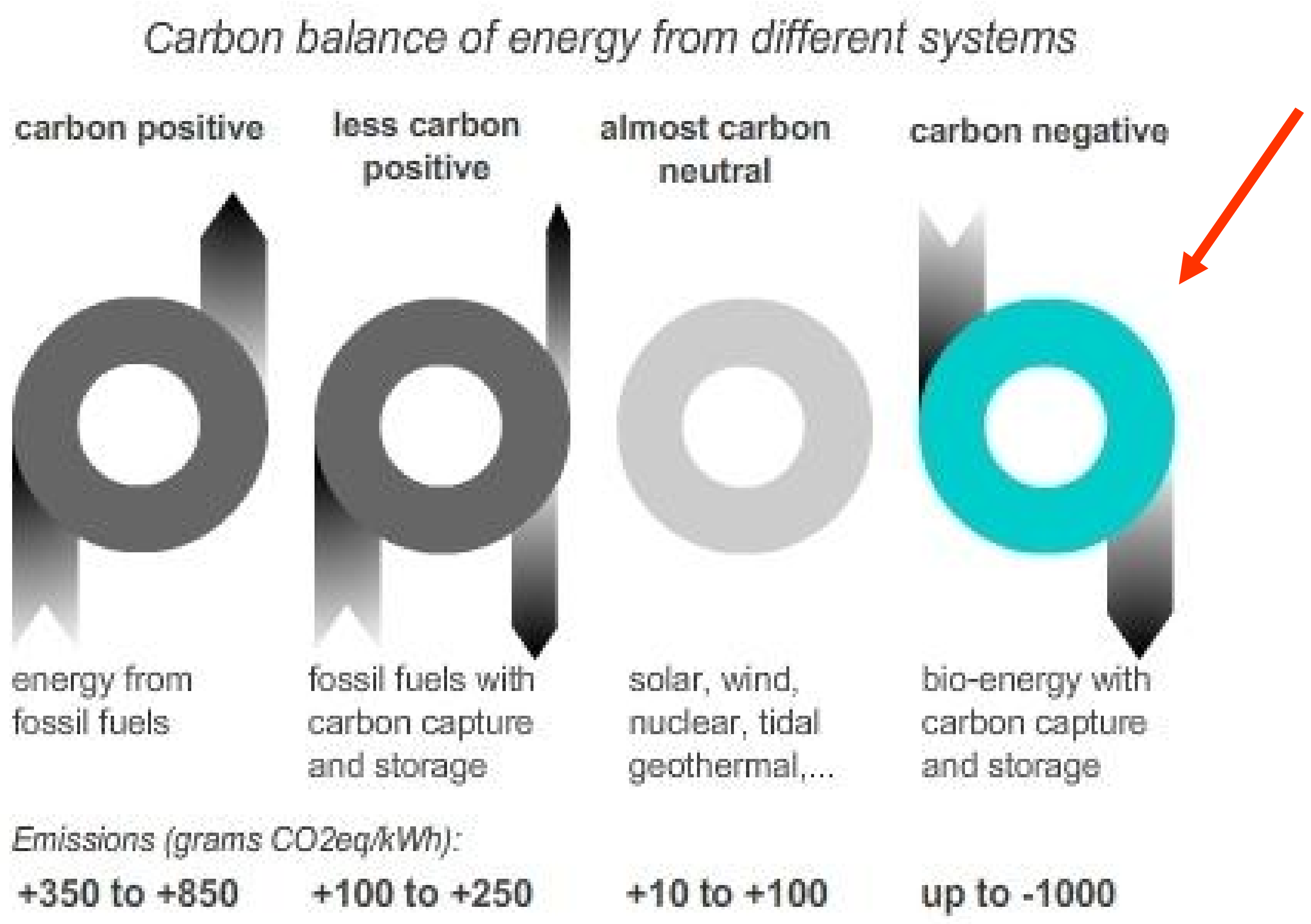

Source: Biopact-carbon

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